THE TOPKAPI SCROLL—GEOMETRY AND ORNAMENT IN ISLAMIC ARCHITECTURE

Gülru Necipoğlu

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Topkapı Palace Museum Library MS H. 1956

Gülru Necipoğlu

with an essay on the geometry of the muqarnas by Mohammad al-Asad

THE GETTY CENTER FOR THE HISTORY OF ART AND THE HUMANITIES

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SKETCHBOOKS & ALBUMS

The Topkapı Scroll—Geometry and Ornament in Islamic Architecture
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Published by The Getty Center for the History of Art and the Humanities,
Santa Monica, CA 90401-1455
 Published 1995
Printed in the United States of America

Library of Congress Cataloging-in-Publication Data

Necipoğlu, Gülru
The Topkapı scroll : geometry and ornament in Islamic architecture : Topkapı Palace Library MS H. 1956 / Gülru Necipoğlu; with an essay on the geometry of the muqarnas by Mohammad al-Asad.
p. cm. — (Sketchbooks & albums)
Includes bibliographical references and index.
ISBN 0-89236-335-5
1. Architectural drawing, Timurid—Catalogs. 2. Architectural drawing—16th century—Asia, Central—Catalogs. 3. Arabesques—Catalogs. 4. Architectural drawing—Turkey—Istanbul—Catalogs. 5. Topkapı Sarayı Müzesi. Kütüphane. Manuscript. H. 1956—Catalogs. I. Al-Asad, Mohammad. II. J. Paul Getty Center for the History of Art and the Humanities. III. Title. IV. Series.
NA2706.A783N43 1995
720′.22′255—dc20 95-14621
CIP

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PREFACE

Drawings can reveal much about architectural practice and design methods, particularly when a building tradition lacks theoretical treatises; the Islamic architectural heritage is a case in point. In the premodern Muslim world references to architecture were often embedded in a wide variety of nonarchitectural texts and "how-to" manuals providing simple instructions without theoretical elaboration. These were complemented by collections of workshop drawings, jealously guarded by master builders as privileged information, and by oral workshop traditions passed on from master to apprentice over the generations.

This makes particularly valuable the few remaining examples of drawings that once mediated the conceptualization and transmission of architectural knowledge in the Islamic world; through these drawings one can begin to penetrate the theory and praxis of architecture and ornament. The scroll preserved at the Topkapı Palace Museum Library and reproduced in its entirety in this volume is an important discovery with major implications for Islamic and general architectural history. In addition to the information it provides about architectural practice, the scroll also raises broader questions pertaining to the interaction between science and art, and promises to be relevant for theories of ornament, abstraction, aesthetics, and vision. My decision to publish this rare document, which I ascribe to late fifteenth- or sixteenth-century Iran, was prompted by the necessity of making it accessible in its original form to a wide audience, both specialists in the Islamic field and nonspecialists.

The scarcity of information about architectural drafting methods in the Islamic world, which are often assumed to have been nonexistent, adds to the significance of the Topkapı scroll, the earliest known document of its kind. Although this scroll throws new light on how architectural design was geometrically conceptualized, recorded, and transmitted in the particular context of late medieval Iran, it also raises more general questions about the mode of geometric patterning that dominated architectural revetments throughout the Islamic world between the eleventh and the early sixteenth centuries.

The scroll's geometric language parallels that of late Gothic architectural drawings, a parallel informed by a shared late antique cultural heritage that often engendered similar design methods and aesthetic sensibilities. No doubt Byzantine architectural practice, too, grew out of this tradition, but unlike the medieval building practice of Europe, which is relatively well documented by extant workshop drawings from the thirteenth century onward, that of Byzantium remains largely undocumented. This is why I have chosen to focus on comparisons with the Latin West, only referring to the Byzantine architectural tradition when relevant information was available.

The Topkapı scroll's distinctive mode of geometric design, dominated by interlocking star-and-polygon patterns in two and three dimensions, came to be known generically in the Iranian world as *girih* (Persian, "knot"). In part 1 this scroll is compared to other surviving scrolls and pattern books attributed to master builders practicing in the Islamic lands, a remarkable group of documents never before treated as a whole. Its provenance, date, graphic conventions, and contents are discussed together with the hitherto underestimated role of such scrolls in disseminating design concepts, techniques, and tastes within the Islamic world. Then, a comparison of the Topkapı scroll with contemporary late Gothic pattern books, in which geometry plays a similar role in generating variegated designs, is followed by an assessment of the scroll's implications for Timurid-Turkmen architectural practice.

A catalog of pattern types, a list of drawings illustrated with overlays recording uninked construction lines, and an appendix complement the first part of the book with more detailed descriptions of the Topkapı scroll's patterns. Since most of these two- and three-dimensional patterns are repetitive variations of geometric compositions generated by similar grid systems, it would have been tedious to describe them in the text. It is suggested, therefore, that the reader become familiar with this catalog and list and the accompanying reproduction of the scroll itself before reading the rest of the book, where the geometric mode of design codified in the Topkapı scroll is historicized and contextualized. The appendix is an essay by Mohammad al-Asad that

addresses the spatial geometry of the Topkapı scroll's muqarnas projections by analyzing in detail a single example chosen from the scroll, informed by the fifteenth-century Timurid mathematician Ghiyath al-Din Jamshid Mas'ud al-Kashi's discussion of the muqarnas. This essay includes computer-generated elevations and sections that dissect the individual components of the chosen two-dimensional muqarnas projection, translating it into volumetric forms.

Part 2 provides a critique of the nineteenth- and twentieth-century secondary literature on the so-called geometric arabesque as a backdrop for the subsequent parts of the book. The Topkapı scroll's distinctive mode of geometric patterning that came to be known as the *girih* was arbitrarily labeled in nineteenth-century Orientalist texts as a subcategory of the arabesque, with its geometric, vegetal, and calligraphic variants. Often interpreted in essentialistic terms, as a timeless component of Islamic visual culture transcending historical analysis, the subject of the geometric arabesque has generated a considerable literature that continues to grow. I had to deconstruct the ahistorical discourse of that literature before constructing my alternative reading of the *girih* as a contextually circumscribed mode of design that emerged and spread in a particular conjuncture. Parts 3, 4, and 5 deal with the political, religious, philosophical, scientific, and aesthetic contexts in which the *girih* was initially formulated in the early medieval Islamic world and subsequently became codified in scrolls that contributed to its long life during the late medieval period. These parts of the book draw upon a wide range of primary sources capable of throwing light on the theory and praxis of geometric design in medieval Islamic settings.

Part 3 traces the historical development and contextual associations of the *girih* mode, exploring where and how it first flourished and continued to be elaborated well into the late fifteenth and sixteenth centuries when the Topkapı scroll appears to have been compiled. Part 4 assesses the contribution of the mathematical sciences to architectural and artisanal practice at a time when *ars* and *scientia* were intimately linked in the Muslim and Christian medieval worlds alike. It focuses on treatises of practical geometry and applied mensuration that played an important role in the education of builders and artisans, comparing the geometric constructions encountered in such practice-oriented "how-to" manuals with those compiled in the Topkapı scroll.

Part 5 analyzes Islamic texts that provide a glimpse of medieval theories of aesthetics and of the psychology of vision that could have informed the taste for geometric abstraction and other modes of abstract patterning. It highlights the similarity of medieval aesthetic theories in the Latin West, Byzantium, and the Islamic world, theories engendered by a shared classical heritage that was remolded in each case by differing monotheistic orientations and cultural memories. The book concludes by addressing the semiotic dimensions of abstract decorative revetments as distinctive visual idioms functioning as identity markers throughout premodern Islamic history. A case is made for the signifying power of nonfigural patterns, generally dismissed as mere decoration. Geometric ornament emerges as a multilayered sign system adaptable to a wide variety of shifting contexts, rather than as a static mold of timeless forms detached from historical memory and context-bound cultural codes of recognition.

This book would not have been written without the encouragement of Filiz Çağman of the Topkapı Palace Museum Library who brought the Topkapı scroll to my attention in 1986. That year she displayed it for the first time in an exhibition on sixteenth-century Ottoman science, technology, and architecture that commemorated the four hundredth anniversary of the death of the architect Sinan. Since the published catalogs of the palace library omit visual documents that lack accompanying texts, the scroll had remained unnoticed until then. Hypothesizing that the Topkapı scroll may have belonged to the Ottoman chief architect's office, Dr. Çağman dated it on the basis of its paper and format, which is comparable to other scrolls from the late fifteenth or sixteenth century preserved in the Topkapı Palace's manuscript collection.

The only other mention of the Topkapı scroll appeared in the review of Bernard O'Kane's *Timurid Architecture in Khurasan* in 1989 by Michael Rogers, who had seen it at the exhibition. He described the scroll as follows:

> It is in superb condition and is evidently a standard compilation of designs from the court architect's office. Since it bears neither date nor draughtsman's signature it is difficult to state definitely when or where it was put together though in Dr. Filiz Çağman's view it could well have been compiled in sixteenth-century Ottoman Turkey. Squinch-nets, however, play no part in Ottoman architecture and the scroll repertoire of designs for these must therefore have come into the palace library from the East. The balance of probabilities would make them Timurid. It is welcome news that it is to be published by Dr. Gülru Necipoğlu-Kafadar of Harvard University for it should be possible to identify designs from it in the Timurid monuments which are published here.[1]

Knowing my special interest in architectural drawings, it was Dr. Çağman who encouraged me to work on the unpublished Topkapı scroll, a generous offer that opened up a subject with fascinating horizons. I am greatly indebted to her for support of my research over the years and for our numerous discussions from which I have benefited so much. I would like to thank Dr. Çağman and the directorate of the Topkapı Palace Museum for helping me obtain the scroll's photographs and for allowing me to publish it. I am also indebted to Betty Tyers of the Indian Department in the Victoria & Albert Museum, who in the winter of 1987 helped me locate the nineteenth-century scrolls of the Qajar state architect Mirza Akbar, arranged for Hugh Sainsburry to photograph them, and gave me permission to publish those photographs. I am grateful to the Victoria & Albert Museum for confirming that permission after her retirement and for allowing me to reproduce in this book selected examples from the Mirza Akbar scrolls.

Asom Urunbayev, director of the Institute of Oriental Studies at the Academy of Sciences in Tashkent, provided invaluable guidance in helping me locate a collection of fragmentary scrolls (attributed to sixteenth- and seventeenth-century Uzbek master builders practicing in Bukhara) in his institute's manuscript library during the summer of 1989. These documents were first kept at the State Public Library in Tashkent and then transferred to the Institute of Oriental Studies in the same city. Because of the transfer and change in catalog number the whereabouts of these scrolls, cited in former Soviet publications, remained unknown. I would like to thank the librarian, Mr. Munirov, who not only found them in the stacks for me but forgave my breaking his chair while using it as a ladder from which to photograph the selected drawings that I was granted permission to publish. I would like to express my gratitude for the warm reception extended by the institute's scholars and staff, which made the rare opportunity of rediscovering and examining the fragmentary Tashkent scrolls that much more memorable.

It was a pleasure to work together on this project with Mohammad al-Asad who, after visiting Istanbul in the summer of 1988 to assist me with copying the uninked, incised construction lines of the Topkapı scroll, agreed to contribute an essay on the geometry of the muqarnas to this book. It was Elizabeth Dean Hermann who finally translated Dr. al-Asad's and my own sketches of the uninked construction lines into the overlays reproduced here in the List of Drawings. Conversations with Oleg Grabar about converting his A. W. Mellon Lectures of 1989 into a book on the theory of Islamic ornament (published in 1992 by Princeton University Press as *The Mediation of Ornament*) often had direct relevance for the Topkapı scroll; as always he enthusiastically shared his ideas. He also made useful suggestions as a reader of the first draft of the book manuscript I submitted in 1991 to the Getty Center for the History of Art and the Humanities, providing invaluable guidelines for my revisions. The comments and constructive criticisms of Yve-Alain Bois, Neil Levine, Muhsin Mahdi, Michael Rogers, Abdelhamid Sabra, John Shearman, and Henri

Zerner on the same manuscript were particularly illuminating.

For providing help, information, encouragement, and support in the course of writing this book I extend my thanks to Chahriyar Adle, Nurhan Atasoy, Sheila Blair, François Bucher, Howard Burns, Yvonne Dold-Samplonius, Massumeh Farhad, Lisa Golombek, William Graham, Renata Holod, Cemal Kafadar, Joseph Koerner, Paul Losensky, Roy Mottahedeh, Nevra Necipoğlu, Ayla Ödekan, Bernard O'Kane, Yasser Tabbaa, Wheeler Thackston, Jr., Irene Winter, and my parents, Ülkü and Hikmet Necipoğlu. I am also indebted to Reif Altoma for translating the relevant secondary literature from Russian into English.

Special thanks go to Evin Erder, Naomi Kasahara, and Kate McCollum, my resourceful research assistants, and to András Riedlmayer, who regularly brought to my attention new publications. Jeffrey Spurr facilitated the search for appropriate illustrations in the visual collections of the Harvard University Fine Arts Library. Acknowledgments for photographs published with the permission of various libraries and collections are included in the captions; all reproductions from books were photographed by John Cook with the exception of figs. 119 and 120, which were photographed by John Kiffe of the Getty Center. The scroll itself was photographed by Hadiye Cangökçe and Cem Çetin. Funding for research travel to Moscow, Leningrad, Tashkent, Samarqand, Bukhara, Baku, Morocco, London, Istanbul, and Paris was generously provided by the Aga Khan Program for Islamic Architecture at Harvard University and MIT, a program that has played an important role in generating scholarly interest in the architectural practices of the Islamic world.

I would particularly like to thank Margaret Ševčenko for her editorial suggestions upon reading the first draft of my manuscript; her expert advice guided me through the initial revision process. The revised text was jointly edited in 1994 by Lynne Kostman and Diane Mark-Walker of the Getty Center with whom it has been a pleasure to work on this project. They were assisted by Tyson Gaskill, Benedicte Gilman, Stacy Miyagawa, and Diane Timba, who spent many hours going over the bibliography and text spellings and obtaining photo permissions. The index was prepared by Carol Roberts. Due to the unexpected delays in the publication schedule, I was compelled at that time to update the bibliography, as much as possible, and to indulge in further revisions that refined some of my arguments. Despite these revisions I have no doubt that skeptics will remain. Having chosen to address a number of controversial issues and to venture boldly into such fields as intellectual history, the history of science, literary theory, and aesthetics, I probably have opened myself to potential criticism. I took up that challenge, however, in the hope of stimulating critical discussion that may help dismantle some of the stereotypes that still enjoy popularity in the study of the visual culture(s) of the Islamic world. I also hope that my book will make a contribution toward bridging the traditional gap between studies on the visual cultures of the medieval Christian and Muslim worlds, a gap that accentuates the latter's exotic "otherness" perpetuated by the essentialistic use of such categories as the arabesque.

Cambridge, Massachusetts
September 1994

1. Rogers 1989, 135.

NOTES TO THE READER

In rendering passages from sources in foreign languages into English, published translations have been used whenever they were available. Otherwise, the translations are my own.

Foreign terms and titles are anglicized when they have entered the language. Arabic and Persian are transliterated, with minor modifications, according to the system used in the *International Journal of Middle East Studies.* Modern Turkish orthography has been used throughout except for direct quotations from Ottoman Turkish texts, which are transliterated according to the system adopted by *İslam Ansiklopedisi.* Persian and Arabic proper names and common terms (except when they are quoted) are spelled without diacritical marks, aside from *ʿayn* and *hamza.* Certain inconsistencies were inevitable due to the different systems of transliteration used in quotations from other books and in the titles of works cited in the bibliography.

To simplify matters, A.D. dates are used throughout. For the general readership, dates are given for most of the names of historical personages and dynasties upon first mention; these dates are repeated in the index for reference. Illustrations are grouped in several categories: figures distributed in parts 1 through 5 (referred to as figs.), the Topkapı scroll reproduction and overlay drawings (referred to as cat. nos.), and Dr. al-Asad's computer-generated elevations and sections (referred to as ills.).

PART 1. THE SCROLL TRADITION

These drawings are not kept separate nor bound as books, but are fastened together side by side with gum, like the Hebrew rolls of the Law, and are preserved in rolls.

—Caspar Purdon Clarke[1]

CHAPTER 1. ARCHITECTURAL DRAWINGS AND SCROLLS IN THE ISLAMIC WORLD

The Topkapı scroll, the point of departure for this study, is the best-preserved example of its kind, with far-reaching implications for the theory and praxis of geometric design in Islamic architecture and ornament. Created by master builders in the late medieval Iranian world, the scroll compiles a rich repertory of geometric drawings for wall surfaces and vaults. Not an isolated case, this important document belongs to a once-widespread Islamic tradition of scrolls in which geometric patterns ranging from ground plans and vault projections to epigraphic panels and architectural ornament in diverse media appeared side by side. An interpretation of the Topkapı scroll's drawings, therefore, must be framed by a discussion of the history of architectural drawings and scrolls in the Islamic world.

There are no known Islamic architectural working drawings from the pre-Mongol era despite occasional textual references to plans. The historian-geographer al-Yaʿqubi (d. 897), for example, described the foundation of the round city of Baghdad by the Abbasid caliph al-Mansur in 762, and he mentioned the tracing of the plan directly on the ground.[2] The historian al-Tabari (839–923) explained how the same plan was delineated with lines traced in ashes, cotton seeds, and naphtha; these materials were then set afire so that the caliph, standing at the center, could watch them burn and thus better visualize the design.[3] Al-Khatib al-Baghdadi's (1002–1071) history of Baghdad referred to both the tracing of the plan on the ground and a detailed drawing sent to the Byzantine ruler in which "Baghdad's land, markets, thoroughfares, palaces, and canals on both the East and West sides were illustrated. . . . When the king was drinking, he would call for the illustration and drink a toast, looking at the drawing. . . . He used to say: I have never seen an illustration of a better built place."[4] Another instance of plans being sent from Baghdad to Byzantium is recorded with reference to the suburban palace of Bryas, built at Constantinople in 823 for the emperor Theophilus on the basis of drawings brought by John the Syncellus, ambassador to the Abbasid court. Architectural drawings were also used in Egypt around that time during the foundation of the mosque of Ibn Tulun in 878. It is reported that when Ahmad Ibn Tulun decided to build this mosque he met with his architect, who drew its sketch on parchment so that the ruler could comprehend the design clearly.[5]

The existence of conventions for representing architecture on parchment can be deduced from an early Koran manuscript discovered in Yemen, most likely dating from before the tenth century when the manufacture of paper spread throughout the Muslim world. Two of the Koran's folios contain architectural representations; each depicts an arcaded mosque shown both in plan and elevation.[6] The use of drawings in medieval Islamic architectural practice is also implied in philosophical and ethical texts. The philosopher al-Farabi's (Alfarabius or Avennasar, 870–950) *Fuṣūl al-madanī* (Aphorisms of the statesman), for example, described the planning architect as the chief of those who execute his drawings (*rasm*) and concepts. Similarly, the philosopher-historian Ibn Miskawayh's (d. 1030) book of ethics, the *Tadhīb al-akhlāq* (The refinement of character), compares the architect-engineer to an army commander whose "supervision is worth a considerable

amount of labor on the part of the people who toil under him and carry out his plans."[7]

The role of the architect in conceptualizing buildings and drawing plans can also be inferred from theological writings that stressed "arguments from design" to prove God's existence. The tenth-century author al-Maqdisi of Balkh, for example, compared the creation of the universe to the construction of a monument. Just as it would be impossible to imagine a finished building to have been created "without the maker who made it, the fashioner who fashioned it, the expert who formed it, and the planner who made its plan," the universe could not have been created without an omnipotent God responsible for all these steps.[8] The same analogy was used by the Sunni thinker and theologian Muhammad al-Ghazali (1058–1111) who said that it was the customary procedure for the architect to sketch the plan of a monument, the builder to build it, and the decorator to decorate it: "However, this is not the case with God Most High. In every instance He Himself is the Planner, Builder and Decorator."[9]

Occasionally more specific references to architectural drawings can also be found. For example, the Persian historian Bayhaqi (995–1077) recorded that the Ghaznavid ruler Masᶜud I (r. 1031–1041) himself drew the plans for his buildings on paper: "He built with his own knowledge of geometry, and drew the lines with his own exalted hand and that among these same facilities his geometry was particularly marvellous."[10] Similarly the thirteenth-century historian Ibn Bibi described how the Anatolian Seljuq ruler ᶜAla' al-Din Kayqubad had determined the plan of the Kubadabad Palace in 1236. The sultan drew the design of each palace structure according to his own conception and indicated the placement of rooms. The palace complex was then built on the basis of the sultan's sketch and under the direction of the supervisor of architectural works.[11]

Several later Muslim rulers are also reported to have drawn plans in order to communicate their ideas to builders. The early fourteenth-century Ilkhanid monarch Ghazan Khan, for example, was described by his vizier Rashid al-Din as having personally sketched the plan (*ṭarḥ*) of his own tomb complex in Tabriz.[12] Another reference from this period to a plan or drawing (*rasmī u ṭarḥī*) on paper (*kāghaz*) appears in the endowment deed (*waqfiyya*) dated 1309 of the Rabᶜ-i Rashidi in Tabriz, a tomb complex built for Rashid al-Din.[13] Although these plans on paper have not survived, the earliest known example of an architectural drawing incised on plaster dates from the same period. It is a 50-centimeter plaster slab showing the projection of a muqarnas quarter vault (fig. 1), which was discovered during the German excavations in Takht-i Sulayman, the site of a Mongol palace built by the Ilkhanid ruler Abaqa Khan in the 1270s. The design on the plate is composed of incised squares, triangles, and rhomboids (corresponding to 45-, 90-, and 135-degree muqarnas units). If doubled, the design could have been used in the construction of a muqarnas half vault, and if quadrupled, it could generate a muqarnas full vault. The slab was analyzed in detail by Ulrich Harb on the basis of remaining muqarnas vault fragments at Takht-i Sulayman, which were composed of prefabricated elements cast in plaster molds and ordered in corbeled tiers with filler units.[14]

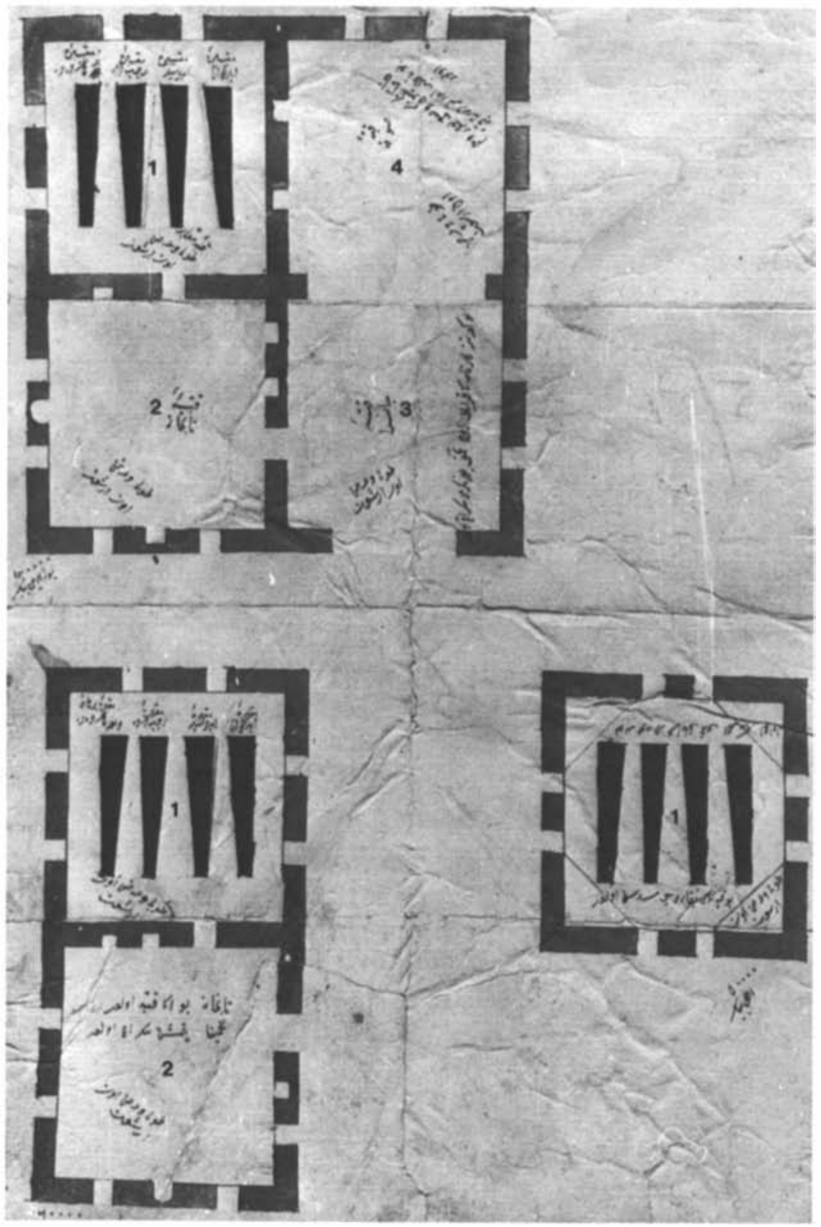
This plaster plate reveals that the complicated geometric method of designing muqarnas vaults must have been rapidly disseminated through such two-dimensional drawings. Texts suggest that drawings did in fact play an important role in the diffusion of fourteenth-century architectural innovations from the Ilkhanid capitals to peripheral areas, contributing to the creation of a unified imperial style associated with court patronage. We know that plans (*ṭarḥ*) were sent from the Ilkhanid imperial capital Tabriz to Yazd for the tomb complex of Rashid al-Din's son-in-law, Shams al-Din.[15] Another exchange of drawings (*ṭarḥ*) between Tabriz and Yazd centered on a hospital project commissioned by Shams al-Din; similarly, plans were dispatched from Shiraz to Yazd for the madrasa complex of the amir Ghiyath al-Din.[16]

These references seem to point to an increasing use of architectural drawings on plaster and paper in Iran and Central Asia during the Ilkhanid period (1256–1336). After the Mongol conquest of these regions—now united with East Asia under the Pax Mongolica (1260–1368)—an abundance of locally produced, inexpensive paper appears to have particularly encouraged architectural drawings on this medium. Rag paper had been introduced to Samarqand by Chinese prisoners of

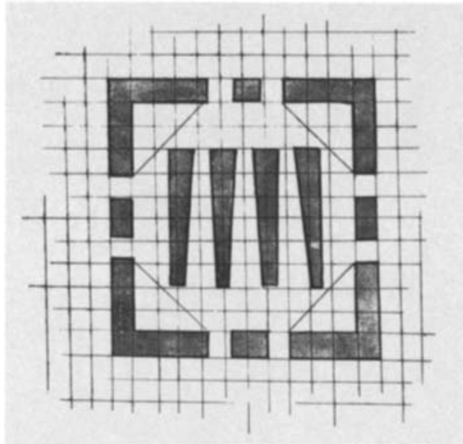
war in 751, and because it was much cheaper than papyrus and parchment, its use had spread throughout the Islamic world after the tenth century. It was not, however, until the Mongols arrived in the 1220s that an extensive paper industry developed in Tabriz and other Iranian towns under Chinese influence—interestingly this occurred around the time that a paper industry was being established in Europe. The implications of this important technological change for the transmission of architectural knowledge in the Islamic world are obvious.[17] The ease of working with a pen on paper would have increased the sophistication of graphic conventions; no longer were architects restricted to the medium of plaster on which designs could only be roughly scratched.

The Timurid-Turkmen cultural sphere, which extended from the Anatolian frontier through Central Asia from the late fourteenth to the early sixteenth century, inherited the Mongol-Ilkhanid architectural tradition as elaborated upon by such Mongol successor states as the Jalayirids (1336–1432) and Muzaffarids (1314–1393). In this period, when the abundance of paper contributed to an unprecedented development in the arts of the book, architectural drawings seem to have been more widely used than ever before. The renowned Timurid architect-engineer Ustad Qawam al-Din Shirazi (fl. 1410–1438), for example, was not only skilled in engineering-geometry (*muhandasī*) and architecture (*miʿmārī*) but also in drawing (*ṭarrāḥī*).[18] That architectural drawings were also used in the Arab world at this time can be deduced

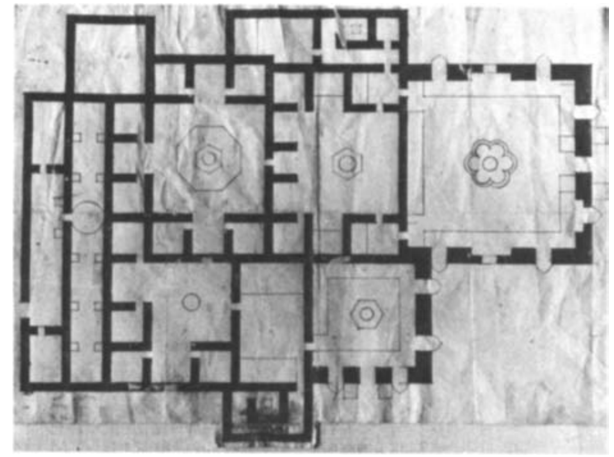
1. Plan of a muqarnas quarter vault discovered in Takht-i Sulayman, Iran, ca. 1270, incised plaster slab. From Harb 1978, pl. 1. Photo: Courtesy Deutsches Archäologisches Institut, Abteilung Teheran.



2a. Ottoman plan with three options for a mausoleum project, fifteenth or sixteenth century, red and black ink on paper. Istanbul, Topkapı Sarayı Müzesi Arşivi, E. 9495/11.



2b. Detail of figure 2a, "dead drawing" of the incised squared grid shown in ink. Drawing by Behçet Ünsal.



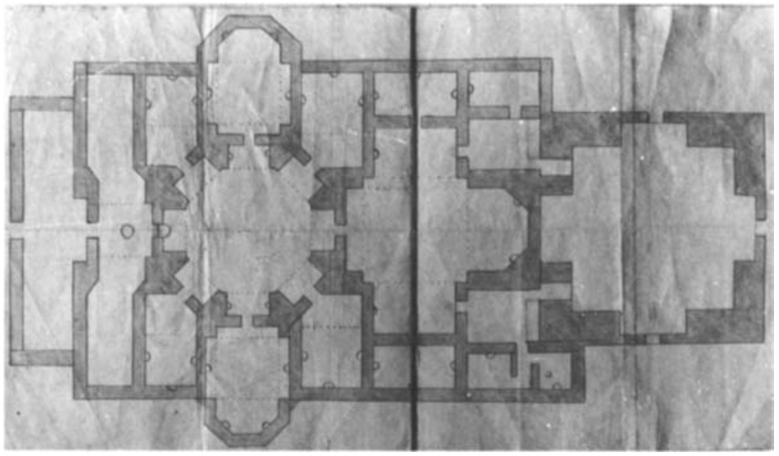
3. Ottoman plan of a double bath, second half of the fifteenth century, red and black ink on paper. Istanbul, Topkapı Sarayı Müzesi Arşivi, E. 9595/7.

from the historian Ibn Khaldun's (1332–1406) reference to plans drawn for monumental projects: "Architecture is also needed when rulers and people of a dynasty build large towns and high monuments [*hayākil*]. They try their utmost to make good plans and build tall structures with technical perfection, so that [architecture] can reach its highest development."[19]

References to the use of architectural drawings on paper multiply considerably during the post-Timurid era, particularly in the written sources of the Ottoman, Safavid, and Mughal empires, attesting to a relatively widespread drafting tradition of which only a few examples have survived. Frequent textual references in sixteenth- and seventeenth-century Ottoman and Mughal sources to architectural drawings sent from dynastic capitals to the provinces testify to their role in disseminating structural and decorative design concepts, a role that has so far been underestimated.[20] The seventeenth-century French traveler Jean Chardin's reference to a palace built by the Safavid shah Tahmasp in Qazvin on the basis of a plan presented to him by a Turkish (presumably Ottoman) architect suggests that occasionally architectural drawings may have moved from one court to another.[21] Indeed, plans from Baghdad and Isfahan are reported to have been available at the court of the Mughal emperor Shah Jahan (r. 1628–1666) whose ability to draw plans (*ṭarḥ*) was described by his court historian ʿAbd al-Hamid Lahori:

> At other times, the superintendents of construction of royal buildings, in company with the wonder-working architects, lay before the critical royal eye plans of proposed edifices. . . . For the majority of buildings he himself draws the plans. And on the plans prepared by the skillful architects, after long consideration he makes appropriate alterations and emendations. And on the final approved plans submitted by the strong pillar of state and firm arm of sovereignty, Yamin al-Daula Asaf Khan, he writes down his sacred judicious notes to serve as a guide for the building overseers and architects of buildings.[22]

On the basis of reports from foreign travelers, it appears that architectural drawings were also widely used in Safavid Iran. Engelbert Kaempfer writing in the late seventeenth century, for example, referred to architects at the Safavid court who prepared plans and drawings for the royal edifices.[23] In 1660 Raphael Du Mans described these architects (*maamar*, i.e., *miʿmār*) as "contractors for making the plan and drawing of a large edifice" but added that their drafting methods differed considerably from those of their European colleagues: "Here they use, depending on their capacity, pens to draw with, but unlike our [architects] they do not know how to represent a big palace in terms of its ichonography, its orthography, or its perspective, and as if it were

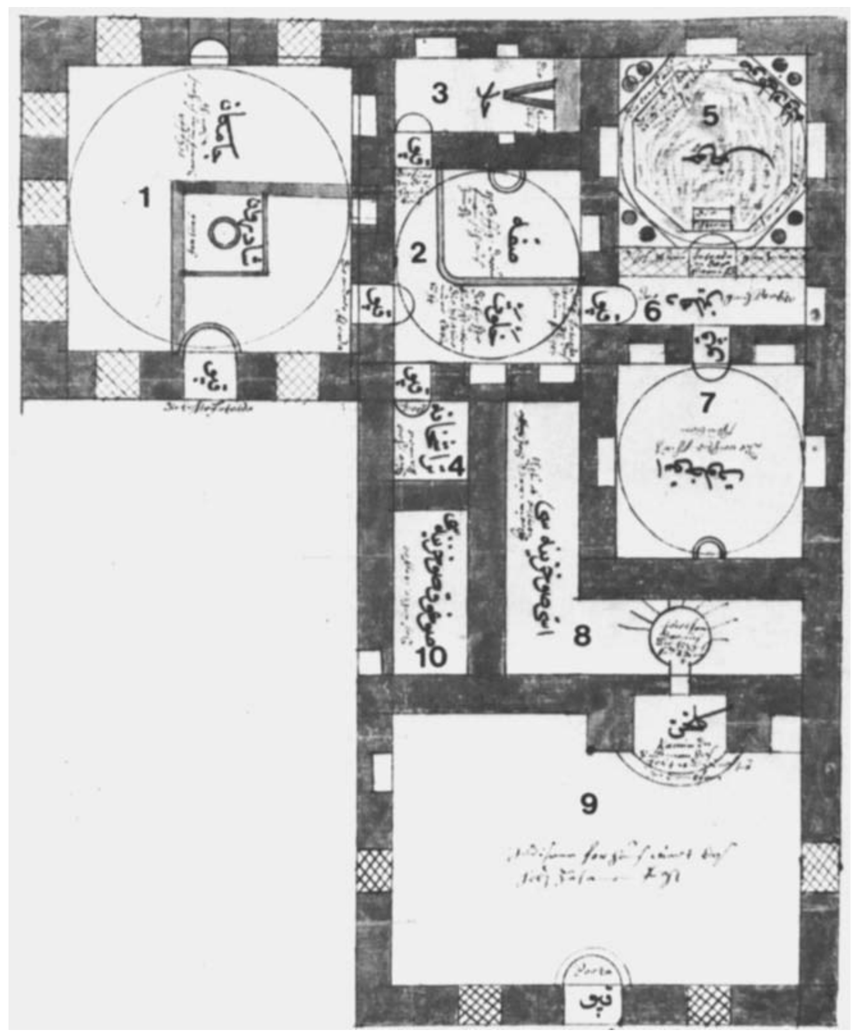


4. Ottoman plan of a bath, second half of the fifteenth century, ink and yellow wash on paper. Istanbul, Topkapı Sarayı Müzesi Arşivi, E. 9495/12.

already capable of being inhabited."[24]

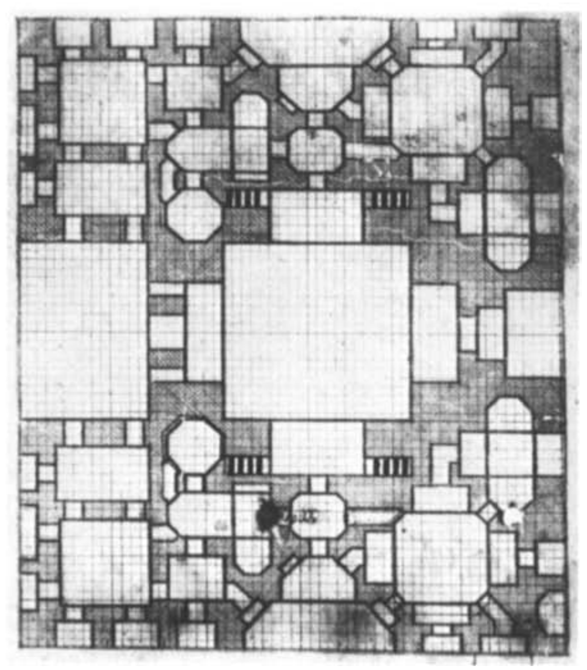
The appearance of such drawings can be deduced from surviving Ottoman ground plans drawn on squared paper, the earliest examples of which are datable to the late fifteenth and sixteenth centuries (figs. 2–5), and from a sixteenth-century miniature, which depicts the Mughal emperor Babur inspecting the laying out of a formal garden. Part of this image shows an architect holding a red tracing board prepared with lines of white chalk forming a squared grid on which the rectilinear garden's plan would have been traced (fig. 6).[25] The use of grid-based ground plans in Ottoman, Mughal, and Uzbek architectural practice probably originated in Timurid-Turkmen precedents, the graphic conventions of which, though adapted to different local traditions, continued to be influential in Rajput India and Qajar Iran during the eighteenth and nineteenth centuries (figs. 7–11).[26] Some of these surviving ground plans are included in scrolls that are similar to the Topkapı scroll, and this makes them directly relevant to the subject of the present study.

Until the recent discovery of the Topkapı scroll, the earliest known Islamic architectural scrolls were those now kept at the Institute of Oriental Studies at the Academy of Sciences in Tashkent. These fragmentary scrolls have been attributed by Soviet scholars to an Uzbek master builder or a guild of architects practicing in sixteenth-century Bukhara. Similar scrolls were still being used by the traditional Muslim builders of Central Asia in

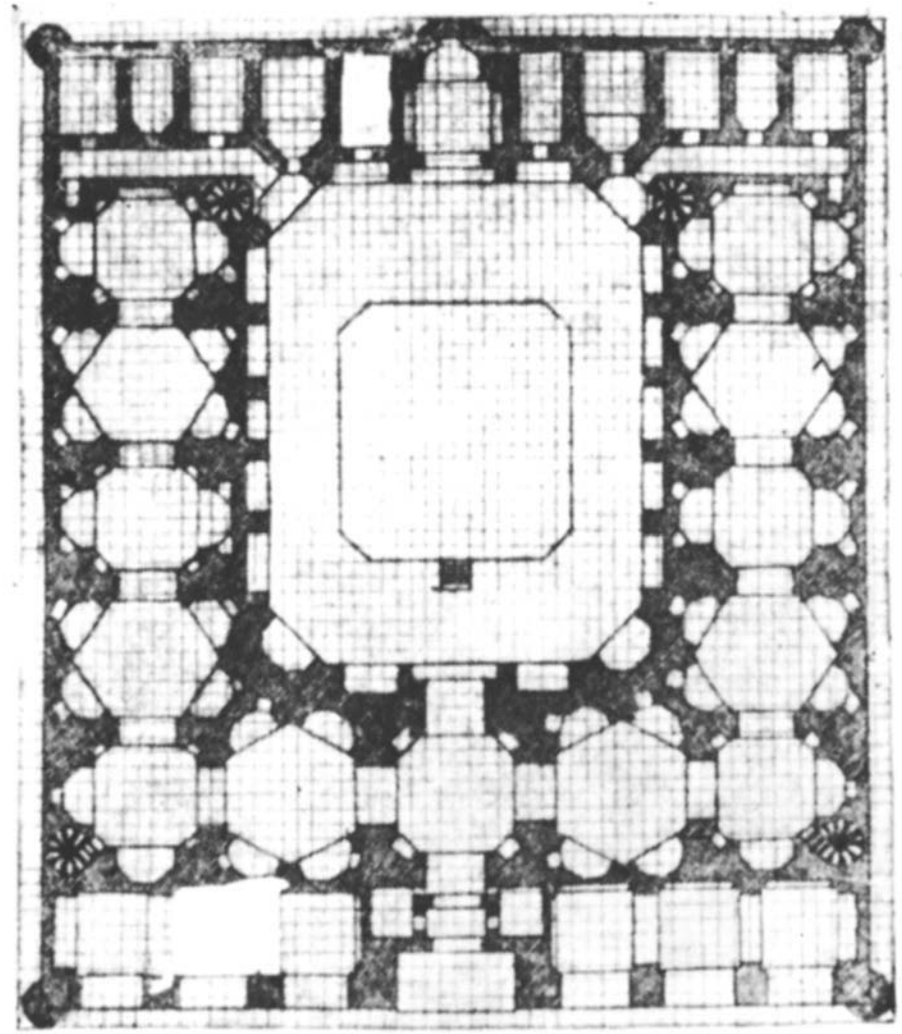


5. Ottoman plan of a bath, late sixteenth century, red and black ink on paper. Vienna, Österreichische Nationalbibliothek, Cod. 8615, fol. 153r.

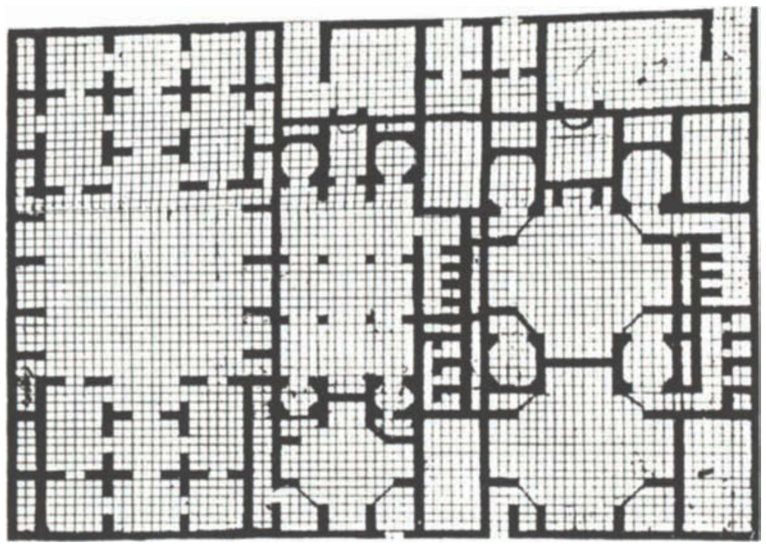
6. Squared tracing board prepared for the plan of a formal garden laid out for the Mughal emperor Babur, detail of a double-page miniature painting. From Babur, *Baburnāma* (Memoirs of Babur), copied ca. 1580. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, I.M. 1913–276 and I.M. 1913–276A.



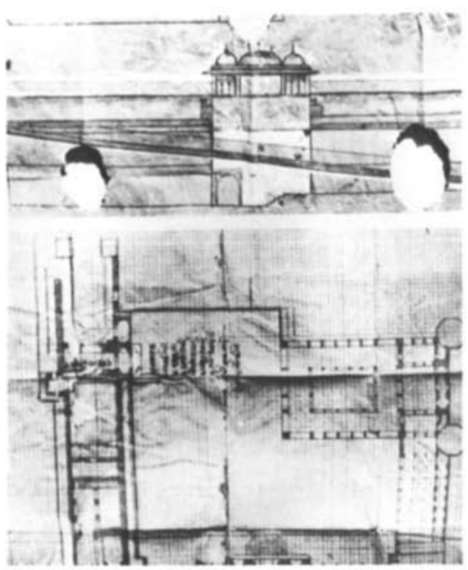
7. Attributed to an Uzbek master builder from Bukhara, plan of a mausoleum or centrally planned pavilion, sixteenth century, red and black ink and colors (orange, green) on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.



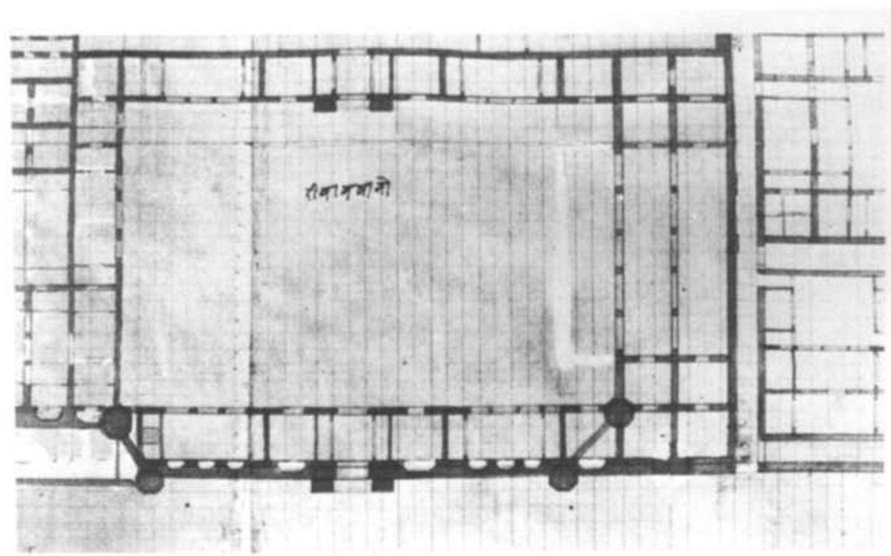
8. Attributed to an Uzbek master builder from Bukhara, plan of a madrasa or caravanserai, sixteenth century, red and black ink and colors (yellow, green) on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.



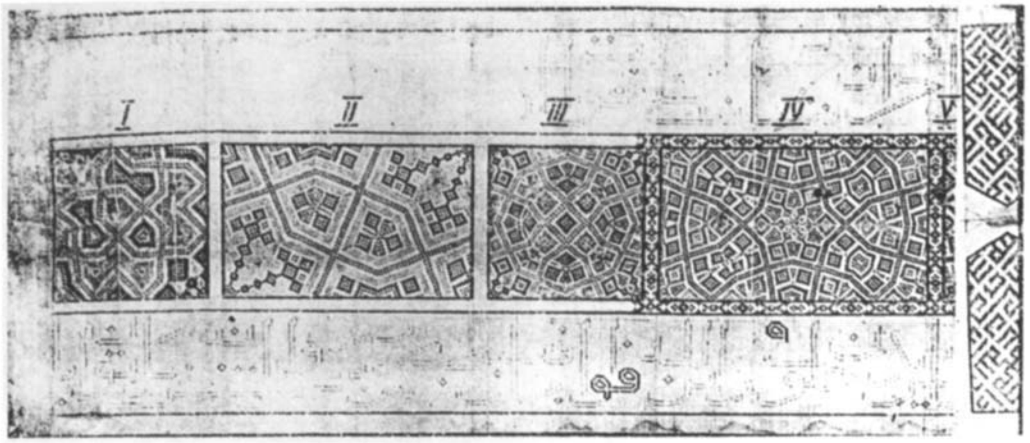
9. Plan of an unidentified building, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London.



10. Plan and elevation of a Rajput palace in Jaipur, eighteenth century, ink on paper. From Tillotson 1987, 104, fig. 129. Jaipur, Rajasthan, City Palace Museum.



11. Detail from the plan of a Rajput palace in Jaipur, eighteenth century, ink on paper. From Begley and Desai 1989, 10, fig. 10. Jaipur, Rajasthan, City Palace Museum.



12. Attributed to an Uzbek master builder from Bukhara, scroll fragment with repeat units for geometric patterns and inscriptions intended for *bannā'ī* brick masonry, sixteenth century, ink and colors on paper. From Baklanov 1947, 103, pl. 1. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

the early twentieth century, and as we shall see, their continued use has been documented in contemporary Iran, Iraq, and Morocco as well.

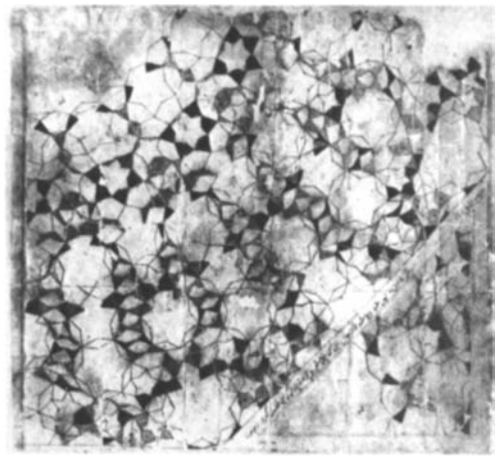
These scrolls, which often combine geometric patterns for two- and three-dimensional architectural revetments, with grid-based ground plans, appear to have been compiled by master builders responsible for coordinating all aspects of a building, including its decorative program. Although they constitute a drafting tradition that was once quite widespread in the Islamic world, it is difficult to determine when such scrolls first came into use. I find it tempting to hypothesize that their scroll format was adopted under influences coming from Mongol China during the Ilkhanid period. However, surviving examples of early thirteenth-century Ayyubid pilgrimage scrolls, which schematically depict the layouts of Islamic sanctuaries in plan and elevation, suggest that the scroll format employed by master builders may already have been in use before the arrival of the Mongols.[27] Given the scarcity of information, the question of when Islamic architectural scrolls originated cannot yet definitively be resolved.

THE TASHKENT SCROLLS

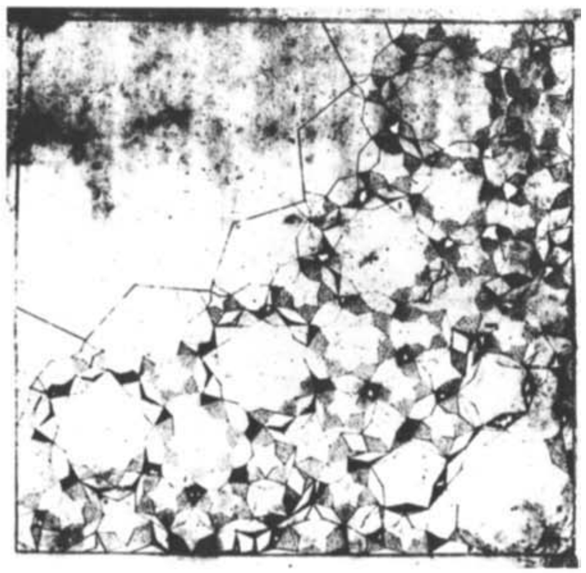
Before turning to the Topkapı scroll itself, let us briefly consider comparable surviving scrolls. The fragmentary Tashkent scrolls, originally belonging to the collection of the Bukhara Museum, were analyzed in several Soviet publications following their discovery in the 1930s. After being restored at the Leningrad Academy of Sciences on the initiative of A. A. Semenov, the curator of manuscripts at the State Public Library in Tashkent, they were transferred to that library and classified by Nikolai Borisovich Baklanov in the early 1940s. They finally ended up as a mixed group at the Institute of Oriental Studies in Tashkent where they are now kept in eight folders, having been cut up for easier preservation and pasted onto separate cardboard sheets. At the time of their discovery the mode of geometric design codified in these fragmentary scrolls was identified as the *girih* (Persian, "knot") by traditional Central Asian master builders who still used such scrolls. This term refers to the nodal points or vertices of the weblike geometric grid systems or construction lines used in generating variegated patterns for architectural plans and decorative revetments in two and three dimensions (each "knot" center where a number of construction lines intersects has an *n*-fold rotational symmetry). The same master builders differentiated this mode of geometric design from curvilinear vegetal patterns governed by a less rigorous, implicit underlying geometry; the latter they identified as *islīmī* (the spiraling ivy or vine-and-tendril motif), a term sometimes corrupted into *islāmī* (Islamic).[28]

The Tashkent scrolls were briefly discussed in two articles by Baklanov.[29] The first of these described the grid-based ground plans and muqarnas vault projections, while the second focused on patterns for two-dimensional geometric ornament. These geometric patterns were also analyzed in 1958 by G. A. Gaganov, who attempted to classify their underlying grid systems.[30] The Tashkent scrolls were subsequently referred to in several Soviet publications, including those of Lazar Rempel', Galina Pugachenkova, Pugachenkova and Rempel', Mitkhat Bulatov, and most recently Iosif Notkin.[31] These studies addressed various issues, including the mathematical analysis of geometric patterns, the relationship of scroll patterns to plan types and architectural revetments seen in the extant Islamic monuments of Central Asia, the mathematical bases of architectural practice, and the implicit theory of geometric harmonization embodied in the Tashkent scrolls. It was Bulatov who observed that the two- and three-dimensional patterns compiled in these scrolls testified to the use of similar geometric processes in architectural design and geometric ornament to create an overall sense of unity in the brick-and-tile based architecture of Central Asia, which thrived on lavish decorative effects.[32]

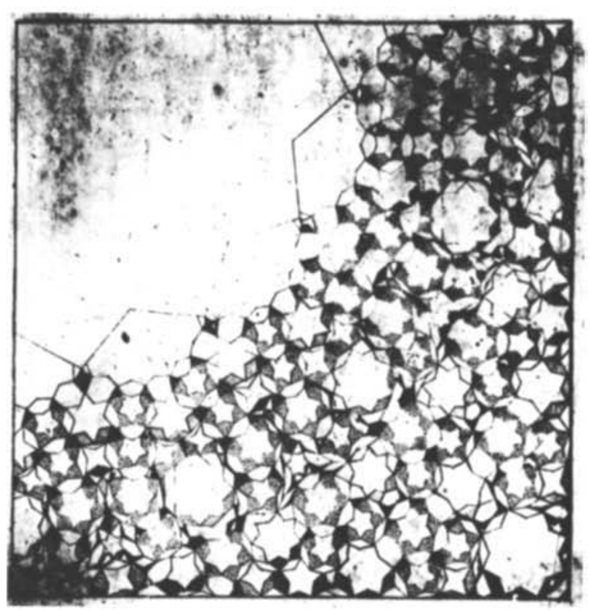
The eight folders in Tashkent contain fragments of several scrolls, the earliest two of which have been dated to the sixteenth century on the basis of their Samarqandi rag paper. The first of these fragments (38 cm × 160 cm) consists of five geometric patterns and a design for a naskhi inscription on squared paper intended for transfer to *bannā'ī* brick masonry (fig. 12).[33] The second fragment, drawn on the same type of Samarqandi paper, also 38 centimeters high, is a part of a scroll with three ground plans superimposed on squared grids and a segment of a fourth plan; these are grouped



13. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth century, red and black ink and color (green) on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.



14. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth century, red and black ink and colors (orange, yellow, green) on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.



15. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth century, red and black ink and colors (orange, yellow, green) on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

together with three ground projections of muqarnas quarter vaults in square frames and another muqarnas vault composed of four stellate domelets decorated with square kufic calligraphy (see figs. 7, 8, 13–15).[34] The polychromatic designs in both of these Tashkent scroll fragments are drawn with a reed pen in black and red ink, highlighted with orange, yellow, ocher tones, and green, often used in combination with stippling or cross-hatching to distinguish different spatial layers collapsed onto a single plane. Their sophisticated draftsmanship and color-coded graphic conventions testify to the advantages of paper over plaster, an observation confirmed by comparing their detailed muqarnas drawings with the simple muqarnas quarter vault projection scratched on the Ilkhanid plaster tablet from Takht-i Sulayman (see fig. 1).

The remaining six folders at Tashkent are generally dated to the sixteenth century but may well include later drawings from the seventeenth century. These folders contain scroll fragments (executed on smaller pieces of paper) with designs typical of Uzbek architecture. They are dominated by projections for muqarnas quarter vaults rendered either in black ink (with some units marked by small black circles) or in black ink highlighted with red, green, and stippling (figs. 16–19). These muqarnas projections, contained in square or nearly square frames of various sizes, are simpler and smaller than those included in the previously discussed scroll fragments (see figs. 13–15).[35] The second largest group of drawings in these six folders, executed in simple black-ink outlines, consists of projections for intersecting arch-net vaults forming stellate patterns (figs. 20–22), accompanied by designs for two-dimensional interlocking geometric patterns (figs. 23–26) and epigraphy. Such arch-net (or squinch-net) vaults—composed of a series of riblike intersecting pointed arch profiles and created by projecting a stellate geometric pattern onto a curved surface—are commonly known as *yazdī bandī* (binding or knot method associated with Yazd); they were widely used in the architecture of Iran and Central Asia from the Timurid-Turkmen period onward.[36]

Executed with simple drafting instruments (ruler, dividing compass, and set squares), the Tashkent scrolls, then, consist of formal drawings of squared ground plans, geometric and calligraphic patterns, and ground projections of muqarnas or arch-net vaults contained in square and rectangular frames. They appear to have been workshop catalogs prepared to preserve the memory of codified two- and three-dimensional ideal patterns; these were generated by various types of underlying geometric grid systems, the construction lines of which are indicated either as inked outlines or as uninked "dead" drawings incised on the paper surface. They are based on the fundamental concept of the repeat unit, the fragment of an overall pattern meant to be multiplied or rotated by symmetry.[37] Unaccompanied by explanatory texts or measurements, these drawings seem to have served as an aide-mémoire for architects and master builders who were already familiar through experience with the coded graphic

16. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

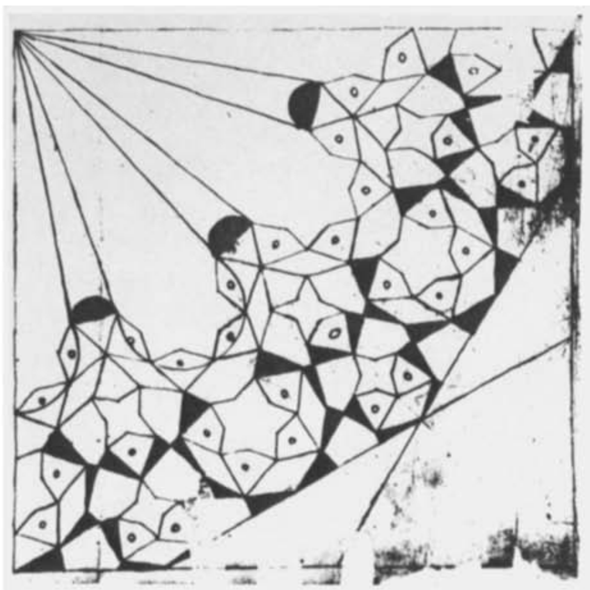
17. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

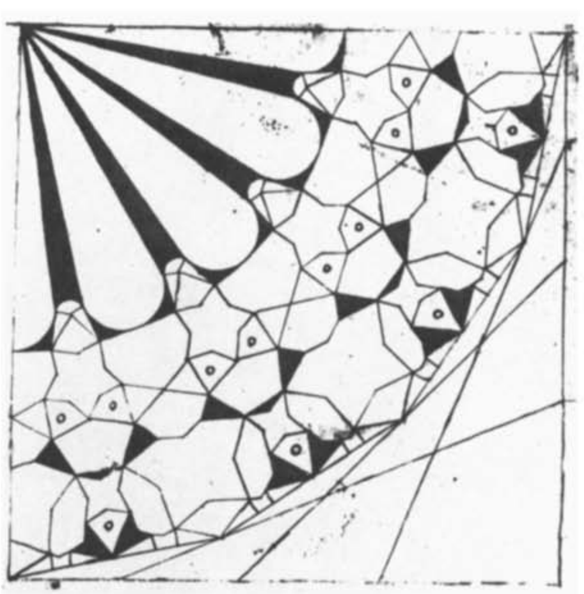
18. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

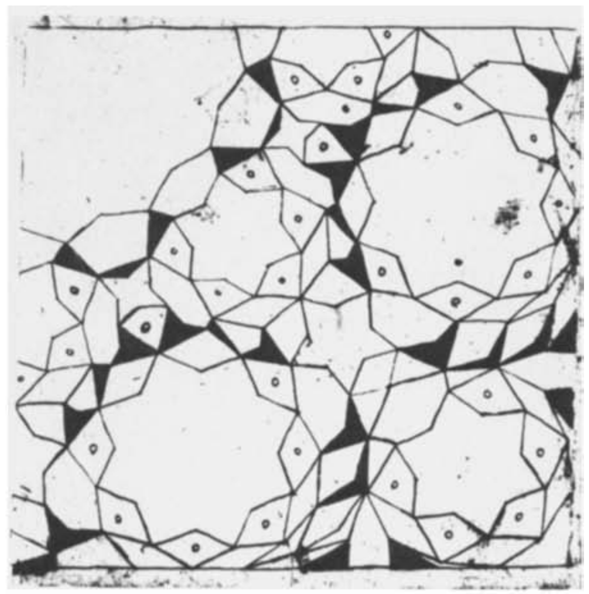
19. Attributed to an Uzbek master builder from Bukhara, plan for a muqarnas quarter vault, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

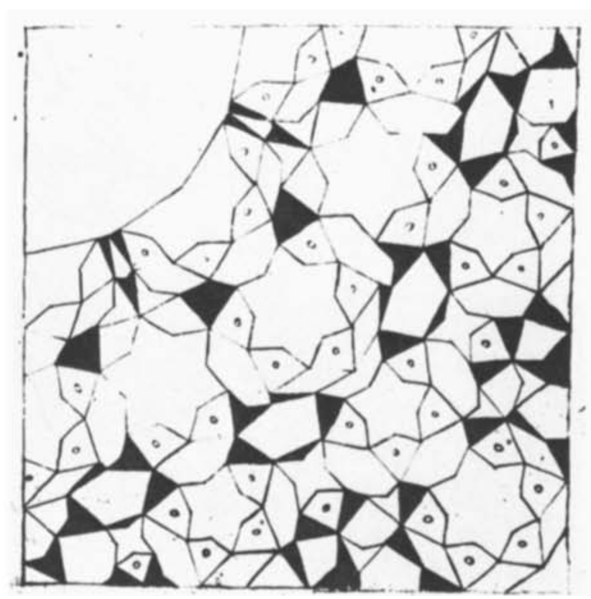
20. Attributed to an Uzbek master builder from Bukhara, plan for a stellate arch-net vault, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

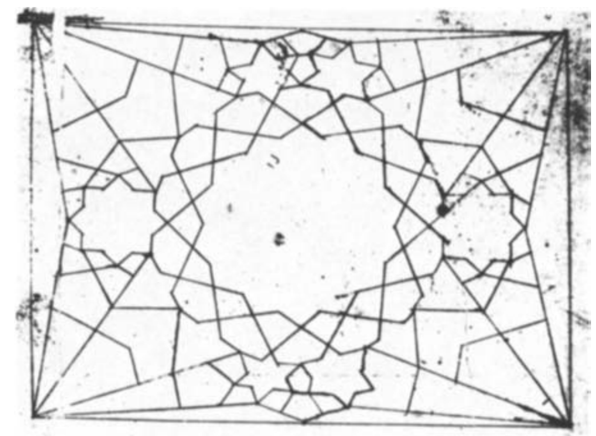
21. Attributed to an Uzbek master builder from Bukhara, plan for a stellate arch-net vault, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

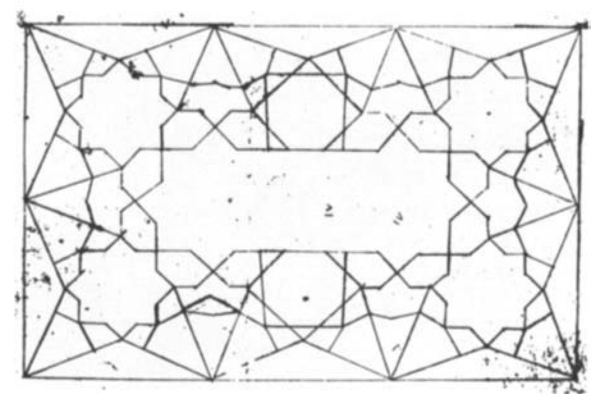


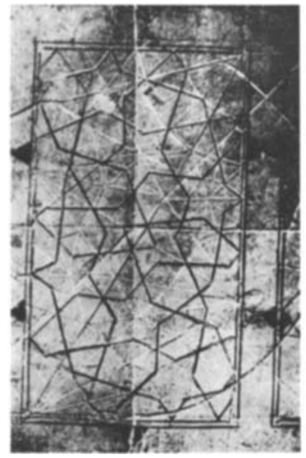


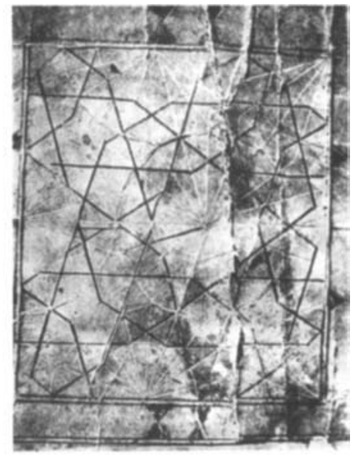






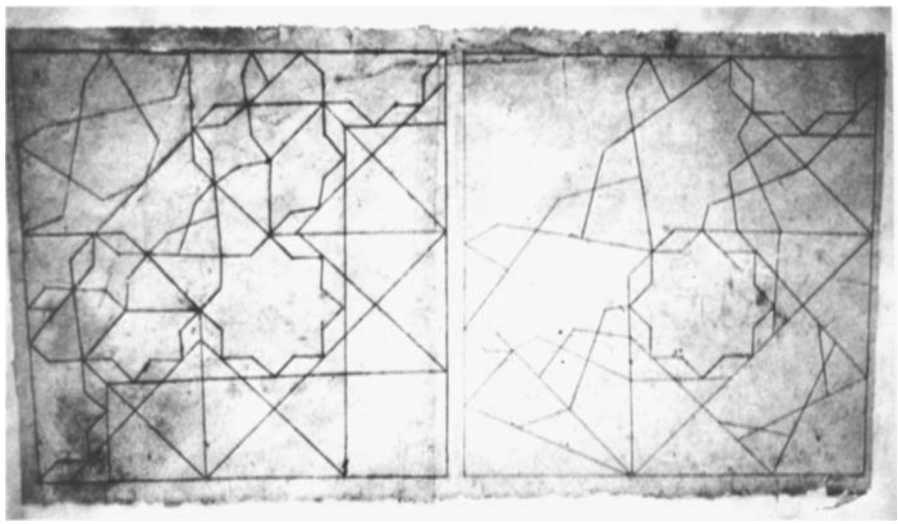






23. Attributed to an Uzbek master builder from Bukhara, scroll fragment with repeat unit for a star-and-polygon pattern, sixteenth century, ink on paper. From Rempel' 1961, 399, fig. 1. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

24. Attributed to an Uzbek master builder from Bukhara, scroll fragment with repeat unit for a star-and-polygon pattern, sixteenth century, ink on paper. From Rempel' 1961, 402, fig. 1. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.



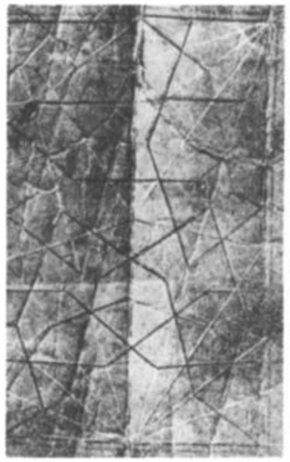
22. Attributed to an Uzbek master builder from Bukhara, plans for two stellate arch-net quarter vaults, sixteenth or seventeenth century, ink on paper. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

language used in them. They functioned as mnemonic devices that assured the preservation and transmission of architectural knowledge over the generations. The abstract patterns codified in the scrolls could be adapted to given dimensions on the construction site where they were often traced full scale on the floor or on walls.[38]

The geometric grid systems and pattern types compiled in the Tashkent scrolls were judged by Soviet scholars to be entirely consistent with the design vocabulary of Uzbek monuments preserved in Central Asia. The ground plans represented standard building types codified in the Timurid period and further elaborated by Uzbek builders, as did the accompanying two- and three-dimensional patterns for decorative architectural revetments. Baklanov related the Tashkent scrolls' decorative patterns based on squared grids to specific developments that occurred in the *bannā'ī* brick masonry technique during the Timurid and Uzbek periods.[39] He observed that these drawings were made to conform to standardized glazed or unglazed bricks of uniform width but varying length (proportionally related to a square module) that could only be laid horizontally, vertically, and diagonally (forming 45, 90, and 135 degrees), a technical constraint that governed the design process. He was able to demonstrate how changing bricklaying techniques affected the types of geometric brick-and-tile patterns used in the Islamic monuments of Central Asia between the tenth and the seventeenth centuries.

Baklanov noted that the evolution of color-glazed bricks, beginning with the introduction of turquoise in the eleventh century and culminating in a wider color range by the fourteenth century, had brought about a standardization of geometric ornament. Between the tenth and the eleventh centuries the absence of color had forced designers to invent more complex geometric patterns executed with a variety of brick and terra-cotta shapes cut in complicated forms and laid at multiple angles to each other. In Timurid and Uzbek buildings erected between the late fourteenth and the seventeenth centuries, the unprecedented expanse of walls that had to be covered with polychromatic surface revetments in a wide variety of media resulted in a relative simplification of geometric compositions, and these became boldly enlarged. Small molded, cut, and fired bricks or terra-cotta pieces were no longer produced in the variety of shapes common in Seljuq and Ilkhanid monuments. The curvilinear outlines seen in earlier geometric revetments had almost completely disappeared from Timurid and Uzbek geometric patterning, which took on a predominantly angular appearance in contrast to the curvilinear vegetal and calligraphic compositions executed in mosaic tiling. Baklanov concluded that it was in this particular context that the somewhat standardized angular *bannā'ī* brick patterns of the Tashkent scrolls were created.[40]

Like Baklanov, Rempel' also detected a standardization in the proportional systems of *girihs* collected in the Tashkent scrolls, reflecting a relative simplification of geometry in the decorative



25. Attributed to an Uzbek master builder from Bukhara, repeat unit for a star-and-polygon pattern, sixteenth century, ink on paper. From Rempel' 1961, 401, fig. 1. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

26. Attributed to an Uzbek master builder from Bukhara, repeat unit for a star-and-polygon pattern, sixteenth century, ink on paper. From Rempel' 1961, 401, fig. 3. Tashkent, Uzbekistan, Institute of Oriental Studies, Uzbek Academy of Sciences.

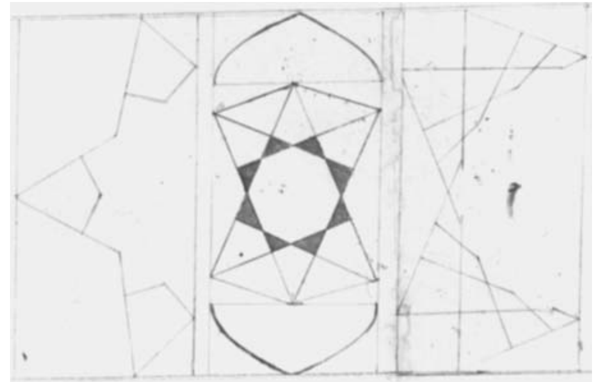
revetments of Timurid and Uzbek monuments. The shapes of the rectangular and square frames that contained *girihs* in these scrolls were not arbitrary; each repeat unit corresponded to a definite proportion and could only have been applied to a surface with the same proportions, regardless of actual size. Nevertheless, unlike the decorative revetments of the eleventh and twelfth centuries, which were custom-made for particular monuments, those included in the Tashkent scroll, he observed, were designed independently of such considerations. To Rempel' this signaled that the "golden age" of geometric ornamentation corresponding to the complex level of Islamic research in the mathematical sciences was over. Now decorators, diverted by the development of color, which was accompanied by a resurgence of curvilinear vegetal and floral motifs executed in mosaic tiling, avoided complex geometry. Rempel' argued that the masters who had created the Tashkent scrolls used simple formulas of practical geometry to create standardized two- and three-dimensional geometric patterns that no longer required an advanced knowledge of computational mathematics or trigonometry.[41]

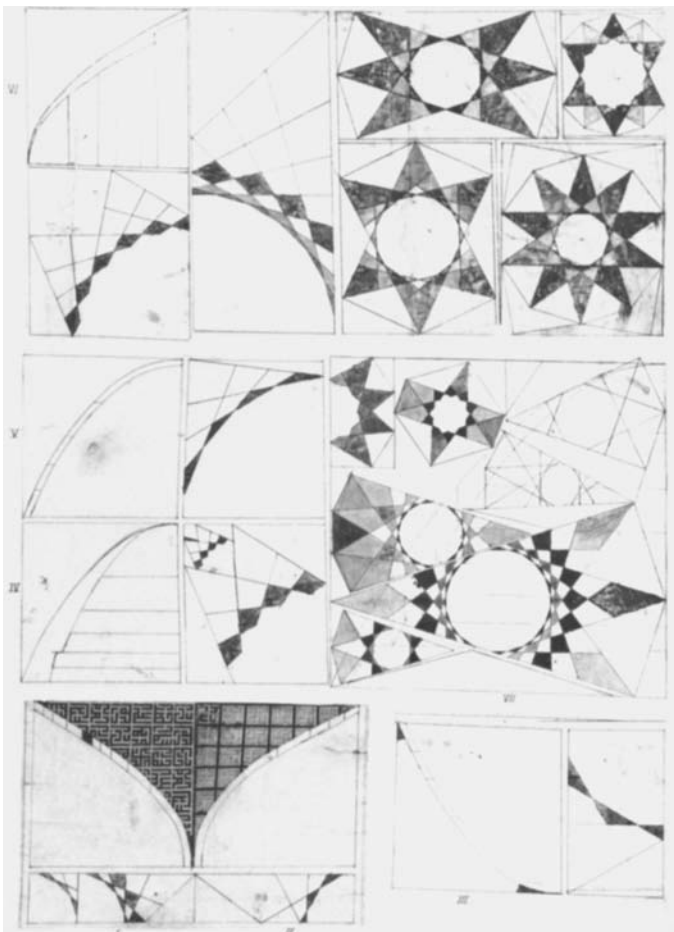
Bulatov agreed that the geometric grid systems used in Timurid and Uzbek monuments to harmonize all aspects of architectural design, from ground plans and wall patterns to decorative vaulting, differed from those favored in earlier periods. He identified six basic grid systems that regulated geometric decoration in Central Asian monuments between the tenth and twelfth centuries (square; square and its derivatives; semisquare and its derivatives, or the double square; equilateral triangle and its derivatives; combination of equilateral triangle and square; and the radial grid). Among these the radial grid came to enjoy particular favor in the Timurid period, as did the simpler grids based on the derivatives of the square and the triangle. By the end of the fifteenth century designers had come to prefer both two- and three-dimensional patterns generated by radial coordinates within square or rectangular repeat units. Bulatov noted that radial symmetries were used by Timurid and post-Timurid designers to harmonize two- and three-dimensional architectural revetments, decorative vaulting, and the spatial arrangement of centralized buildings. The direct translatability between planar and spatial geometry, based on a limited number of geometric progressions allowing a wide range of variation, contributed to the sense of unity in Timurid architecture and its surface decoration, reflecting an intimate relationship between the principles of architectural design and ornament.[42]

In the Tashkent scrolls the most common grid systems used are the square or 45-degree rotated-square grid, drawn in black ink (used in squared ground plans, square kufic calligraphy, and patterns for *bannā'ī* brick masonry), and the radial grid, scratched on paper with the sharp point of a compass but not gone over in ink. Based on dividing concentric circles into equal arcs by equidistant radii, along which rows of polygons and star polygons inscribed in smaller subsidiary systems of circles are formed, the radial grid constitutes the basis of both two- and three-dimensional geometric designs, including arch-net and muqarnas vault projections. It is often used in conjunction with other grid systems and axes of dynamic symmetry, resulting in composite networks of uninked "dead" drawings that generate complex multilayered patterns.

The radial grids of the arch-net and muqarnas vault projections in the Tashkent scrolls have recently been analyzed by Notkin (see figs. 13–22). In an earlier study of muqarnas types used in the Shah-i Zinda complex at Samarqand, Notkin had concluded that from the end of the fourteenth century onward radial grids, which were particularly suited to the versatile medium of plaster, had started to replace rectilinear networks used in previous muqarnas vaults composed of less flexible terra-cotta units. The radially arranged tiers of the Tashkent scrolls' muqarnas drawings, replete with a multiplicity of stars, were largely intended for the plaster medium. Notkin identified them as Uzbek elaborations of the radially symmetrical plaster muqarnas type that had experienced an unprecedented inventiveness in the late Timurid period. He attempted to decipher the coded conventions of these muqarnas drawings by separating their individual tiers, an exercise that led him to conclude that the Tashkent scrolls (despite their intricate coding of corbeled spatial layers) contain ambiguous representations open to several alternative readings. Regarding this ambiguity as a measure intended to protect secret craft knowl-

27. Detail from a scroll showing stellate arch-net patterns and arch elevations, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, red and black ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Library, MS no. 55.





28. Scroll fragments showing stellate arch-net patterns for vaults, arch elevations, and *bannāʾī* brick masonry designs for arch spandrels, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, red and black ink and colors (yellow, pink, blue-gray) on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 32.

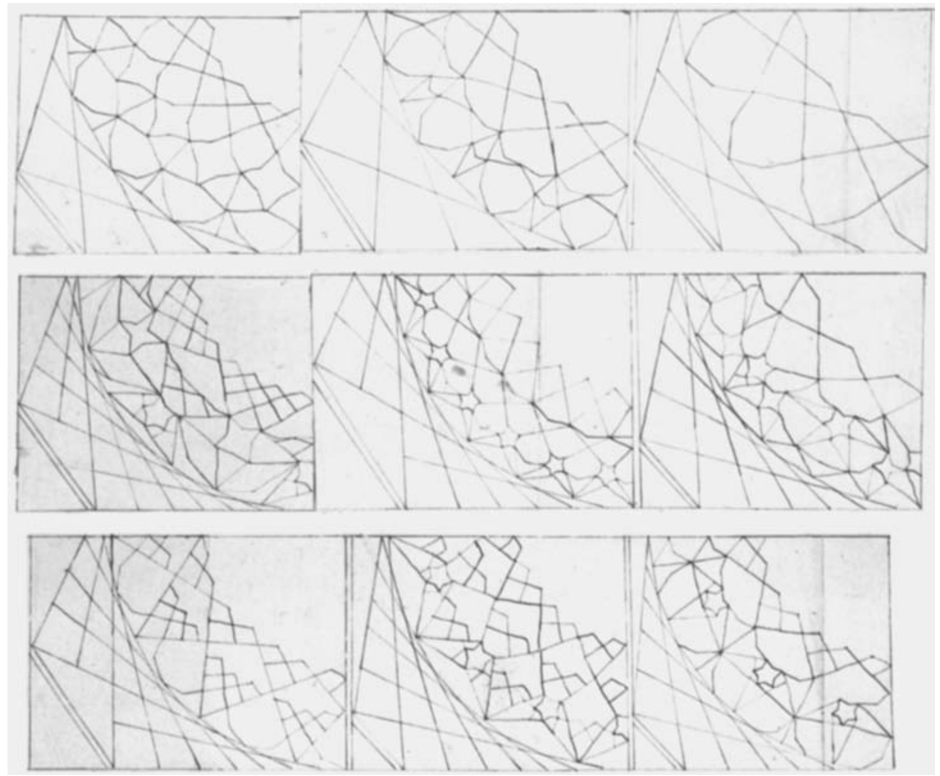
edge by enabling the designer alone to translate the coded drawings into spatial forms, Notkin identified these muqarnas drawings as the creations of a Bukharan guild of master builders and architect-engineers (*muhandis*) active in the sixteenth century.[43]

The fragmentary Tashkent scrolls almost certainly reflect the Timurid-Turkmen drafting methods of the fifteenth century, if not earlier, given the stylistic conservatism of sixteenth- and seventeenth-century Uzbek architecture in Bukhara, which often perpetuated already established formulas.[44] Their graphic sophistication in comparison to later scrolls used by elderly Muslim master builders practicing in nineteenth- and early twentieth-century Central Asia was immediately noted by Soviet scholars. Despite their simplicity, however, the more recent scrolls testify to a relatively unbroken tradition of architectural practice in Central Asia from at least the Timurid period onward.[45]

NINETEENTH- AND TWENTIETH-CENTURY SCROLLS

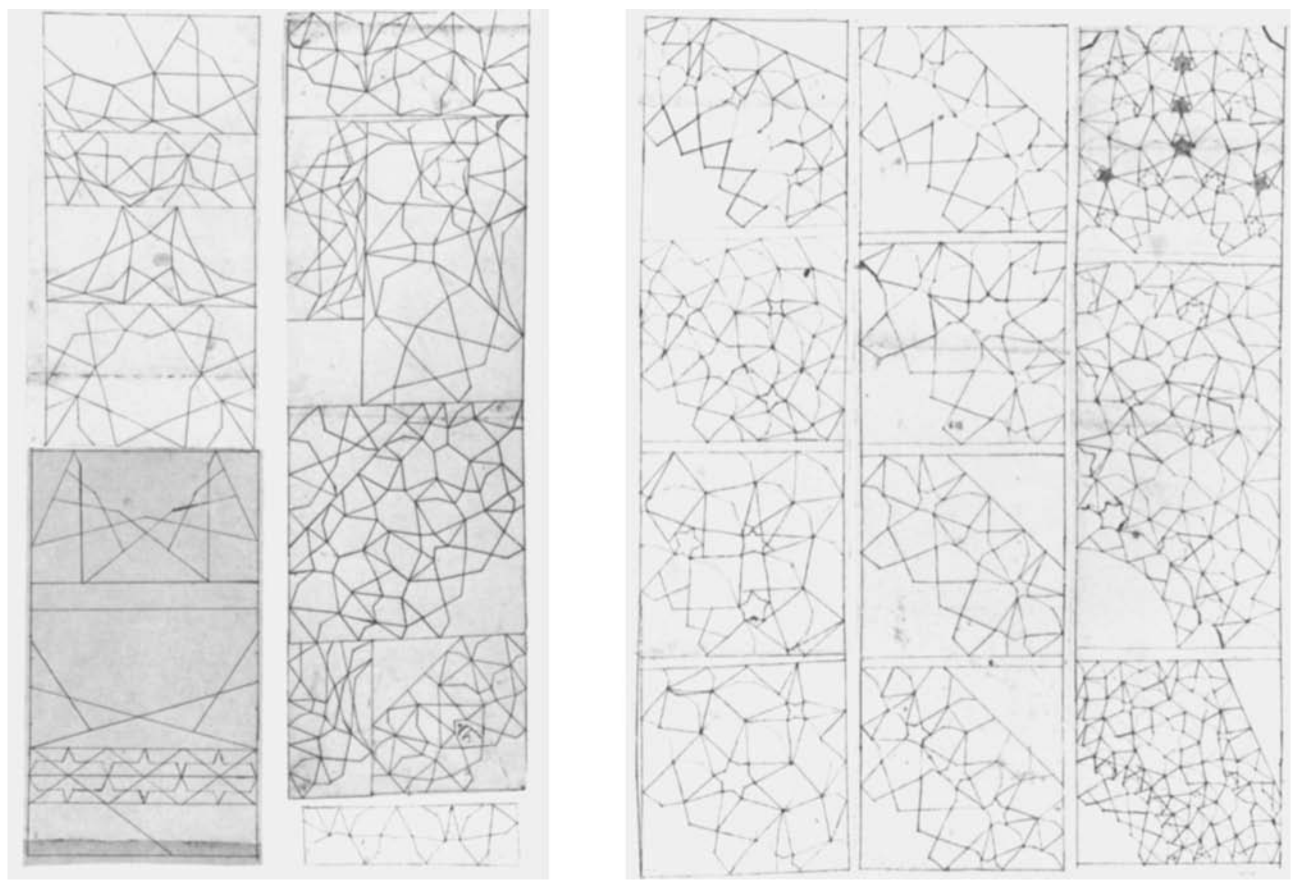
Thanks to the resident architect of the British Embassy in Iran, Caspar Purdon Clarke, a Freemason who managed to penetrate the secrecy of the masons' guild in Tehran, we know that scrolls with architectural drawings similar to those documented in Central Asia at the turn of this century were also being used by contemporary Iranian master masons. While he was overseeing the construction of the British Legation Building at Tehran, Clarke was "allowed to acquire a quantity of these roll books, most of which are now in the Library of the South Kensington Museum" in return for having taught the guild master's son the modern technique of casting plaster in gelatin molds.[46]

These scrolls, preserved at the Victoria & Albert Museum, are attributed to the nineteenth-century Qajar state architect (*muhandis al-dawlat*) Mirza Akbar (figs. 27–36). They are identified in the museum entry as a "collection dispersed at the death of Mirza Akbar, acquired from Oostads [i.e., *ustād*, "master"] Khodadad and Akbar, Master builders of Teheran, by C. Purdon Clarke, Superintendant of Her Britannic Majesty's Works in Persia, January 1876." Today only two of these nineteenth-century scrolls are preserved in their original format, rolled and protected by leather flaps. Their uninked "dead" construction lines, scratched on the paper with a pointed tool by means of which variegated designs were generated, are described in a note scribbled on one of the scrolls: "The uninked drypoint tracing indicates the basis of the formation of figures."[47] The first scroll is on blue paper (22.5 cm high) and is identified as "Roll of Standard Patterns for Tessellated Work"; it provides compositions for two-dimensional geometric patterns in black ink, which could be applied in several media. The second scroll, on white paper (20.5 cm high), is identified as "Roll of Standard Patterns for Groined Vaulting"; it gives projections for stellate arch-net



29. Scroll fragments showing muqarnas quarter vaults with arch-net squinches, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 41.

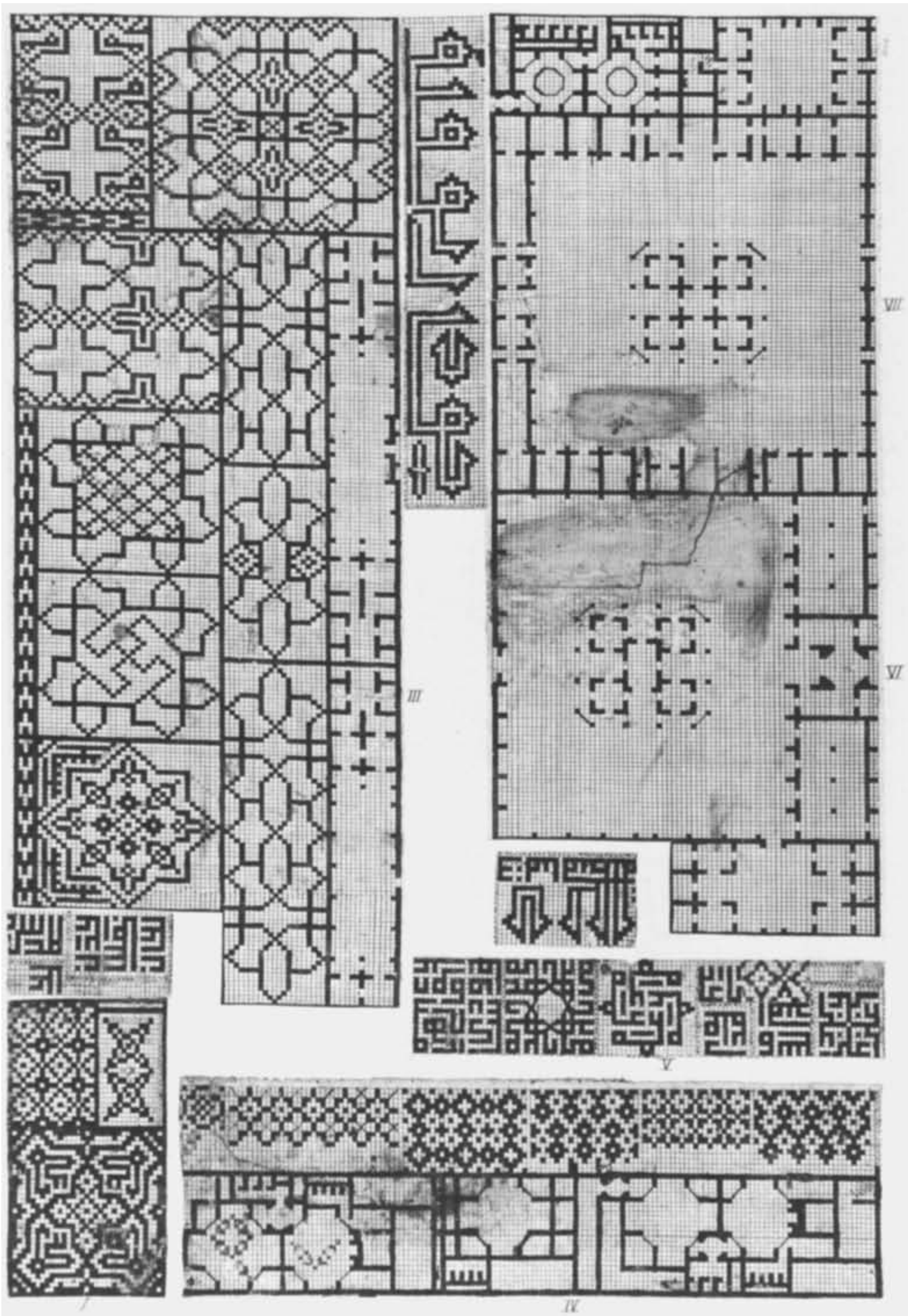
30a, b. Scroll fragments showing muqarnas quarter vaults and muqarnas fragments mixed with arch-net vault patterns, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, red and black ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS nos. 38–39.

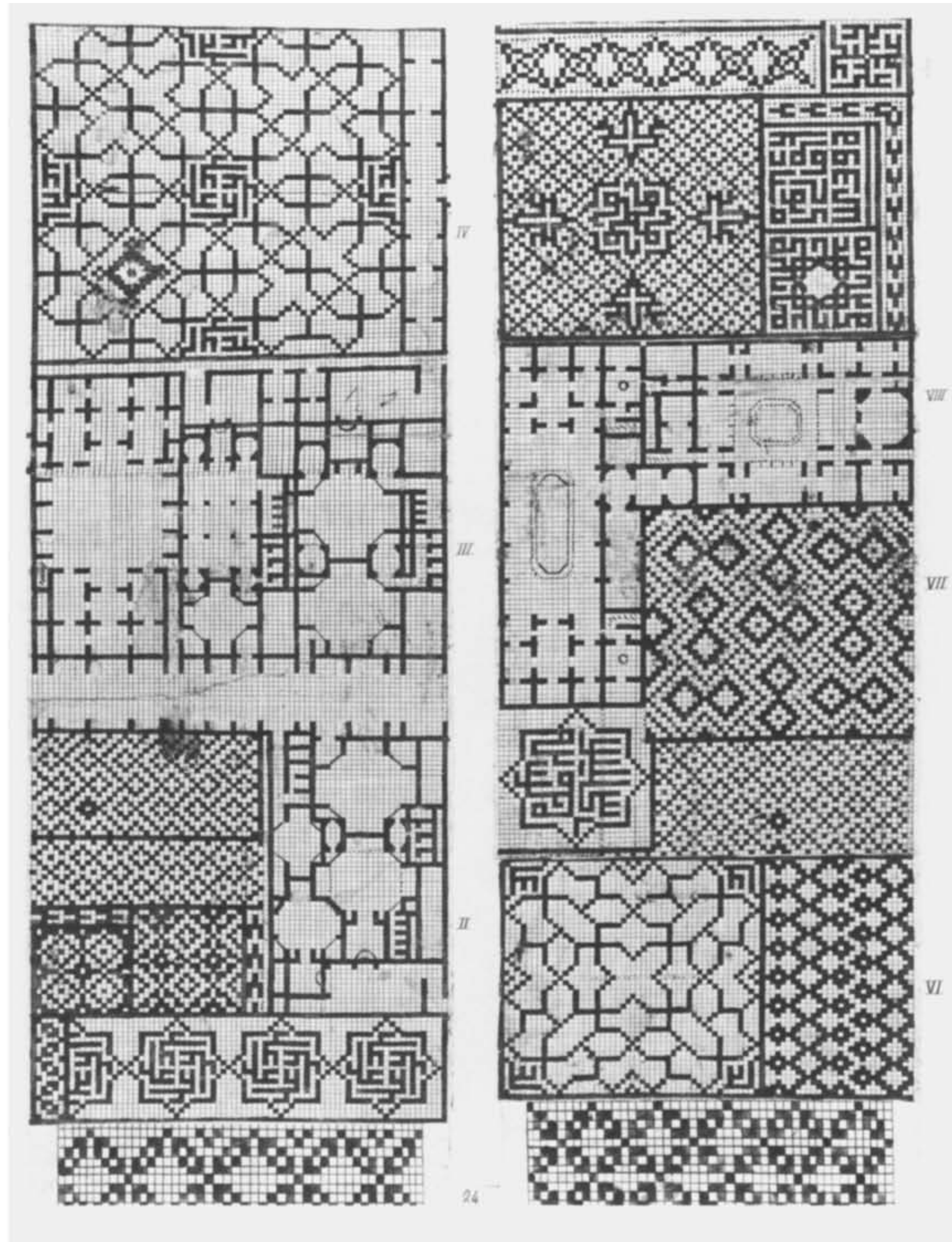


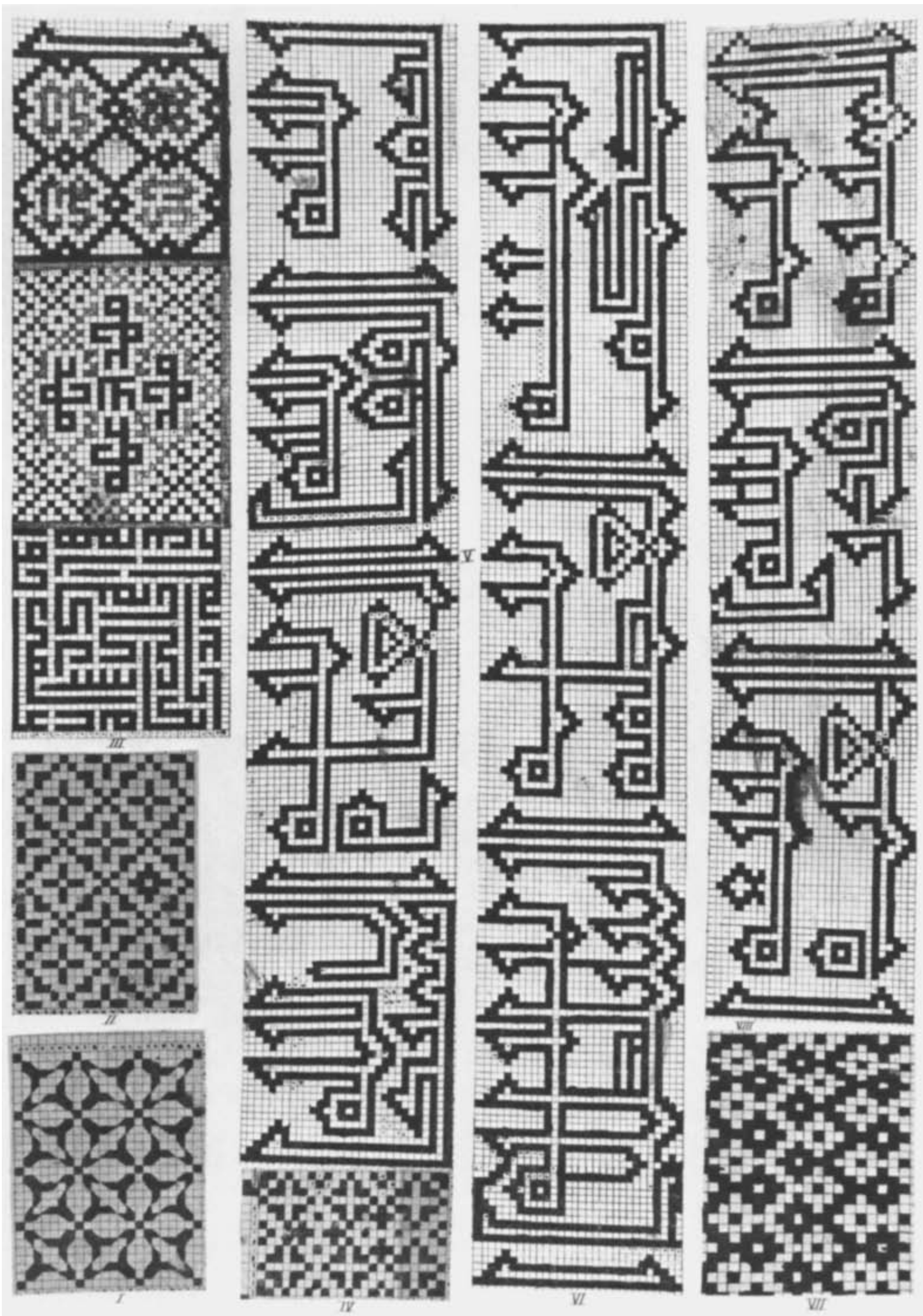
vaults executed in black ink, occasionally highlighted in red (see fig. 27).

The other, more fragile scrolls were cut up in London (as were those in Tashkent) and pasted in no particular order onto fifty-three large sheets of cardboard. They are now kept in the Indian Department of the Victoria & Albert Museum (see figs. 28–36).[48] The black-ink outlines of these pasted drawings, which generally provide the repeat unit of the overall design, were once again generated by various grid systems and often highlighted with red and other lively colors (yellow, orange, pink, and blue-gray), like the drawings in Tashkent. This nineteenth-century collection of designs and pounces, which may contain earlier specimens, consists of drawings for the construction of arch curves and ornamental details for spandrels, capitals, borders, vault projections (arch-net and muqarnas), square or hexagonal tiles, mosaic tile work, geometric patterns and inscriptions intended for *bannā'ī* brick masonry, geometric window lattices, and ground plans on squared grids (as well as Qajaresque figural sketches of fairies, birds, animals, mythical creatures, flowers, cypress trees, and vegetal patterns). Although the collection includes many geometric patterns similar to those in Tashkent, it also contains Europeanizing motifs and eclectic compositions inconsistent with a Timurid-Turkmen design repertory (see fig. 36).

The Mirza Akbar drawings are more sketchy in nature than those in Tashkent. Moreover the former include both freehand figural motifs





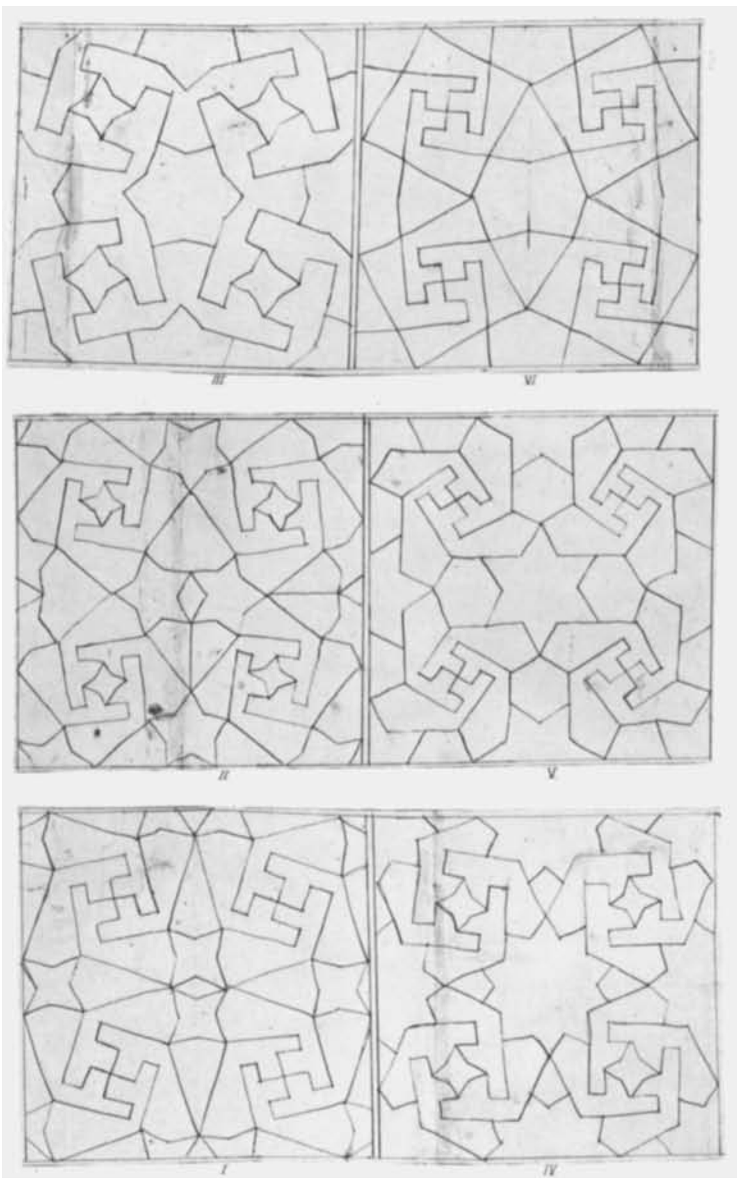


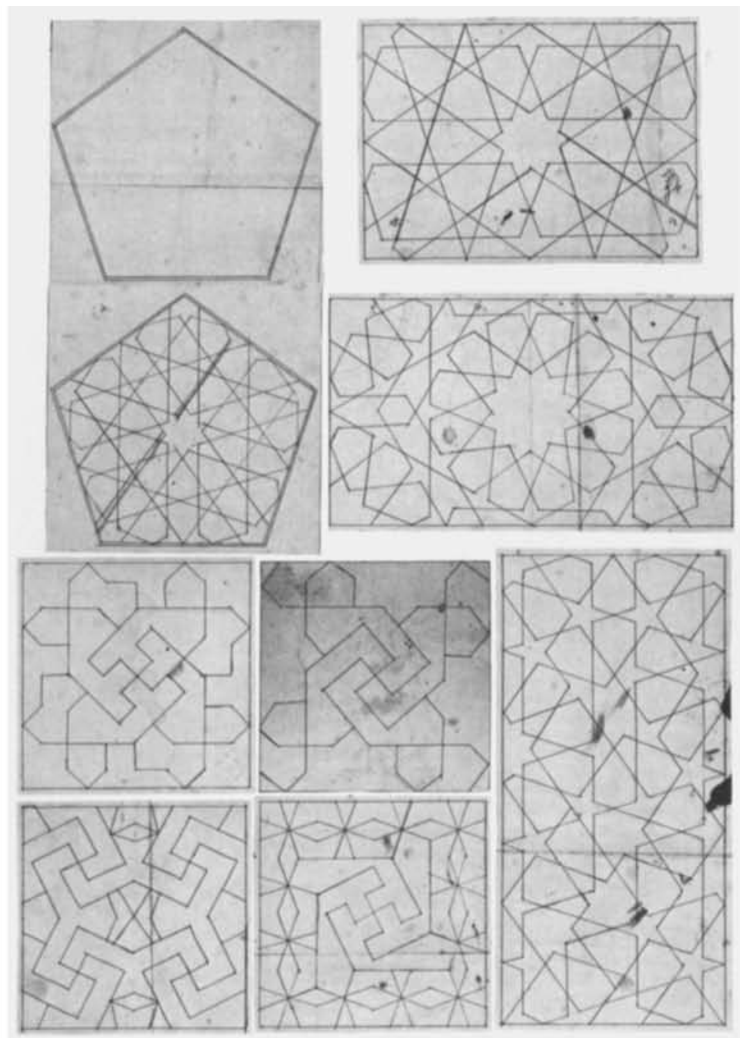
31. Scroll fragments showing geometric patterns, inscriptions, and ground plans drawn on squared grids, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 25.

32. Scroll fragments showing geometric patterns, inscriptions, and ground plans drawn on squared grids, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 24.

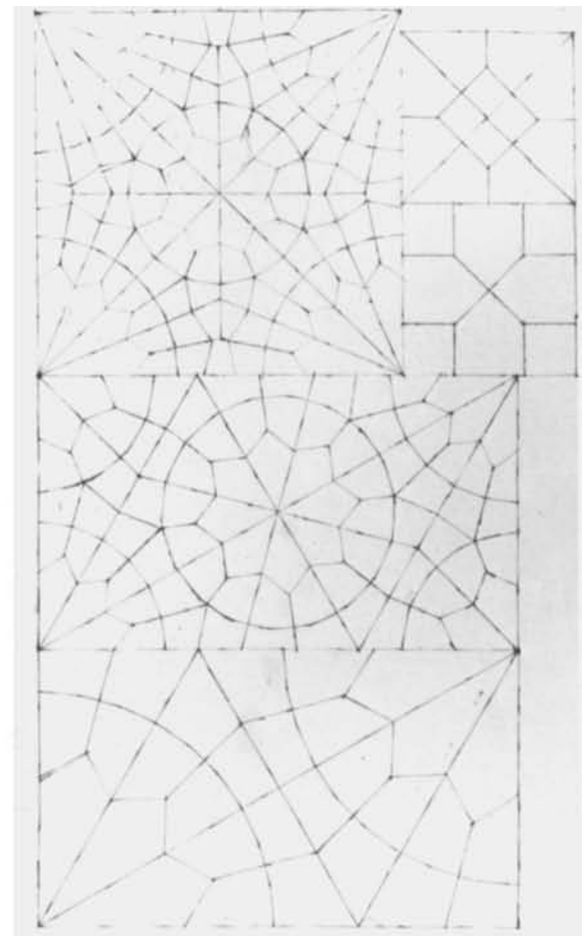
33. Scroll fragments showing geometric patterns and inscriptions drawn on squared grids, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, red and black ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 20.

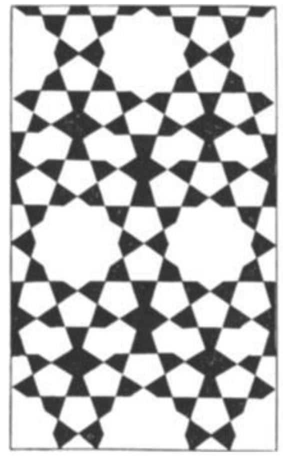
34a, b. Scroll fragments showing square, rectangular, and pentagonal repeat units for geometric tile panels, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, red and black ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS nos. 21–22.

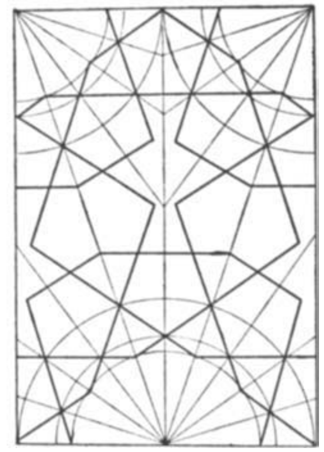




35. Scroll fragment showing geometric patterns for window grilles, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 44.



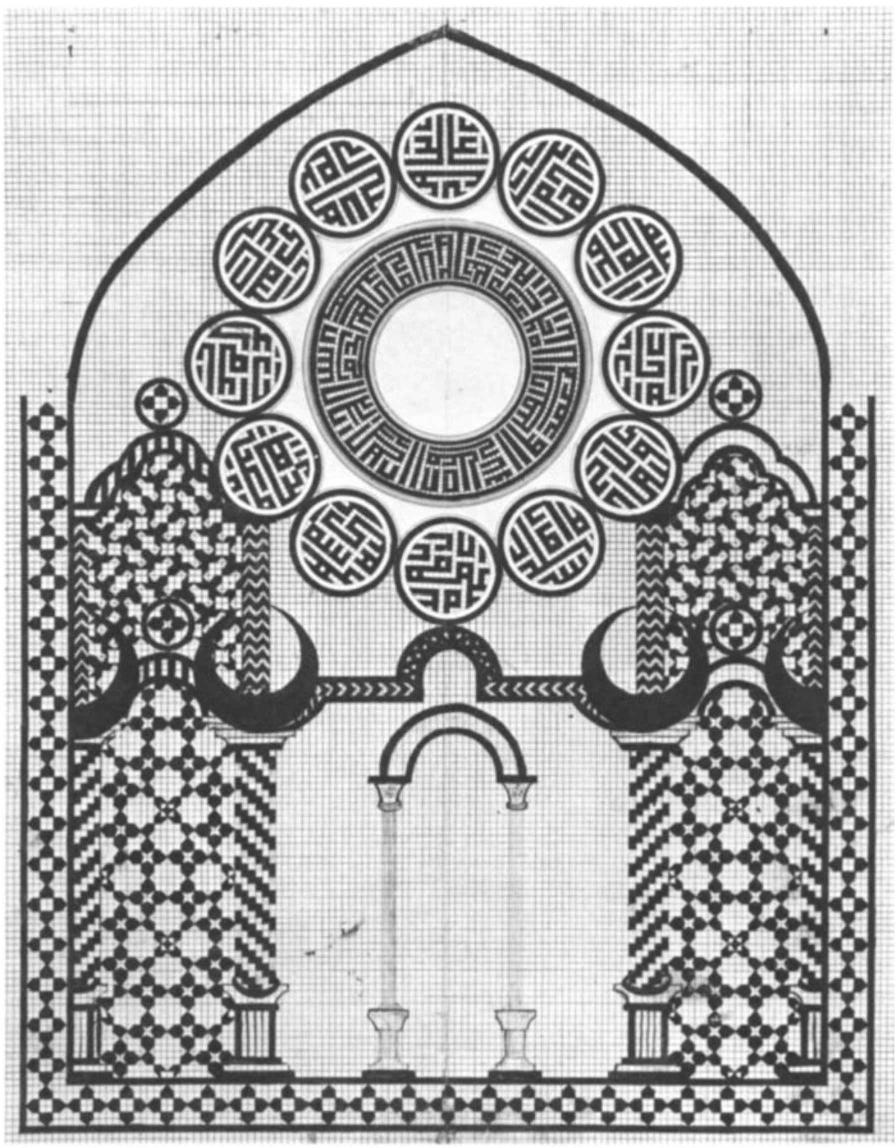




37a. Archibald H. Christie, drawing of a star-and-polygon pattern from the Mirza Akbar scrolls. From Christie 1929, 257, fig. 290. Photo: By permission of Oxford University Press.

37b. Archibald H. Christie, diagram showing the uninked radial grid lines of figure 37a. From Christie 1929, 258, fig. 291. Photo: By permission of Oxford University Press.

36. Scroll fragment showing the elevation for a mihrab drawn on a squared grid, from the collection of drawings once belonging to the Qajar royal architect Mirza Akbar, late eighteenth or nineteenth century, ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Indian and South-East Asian Section, MS no. 14.

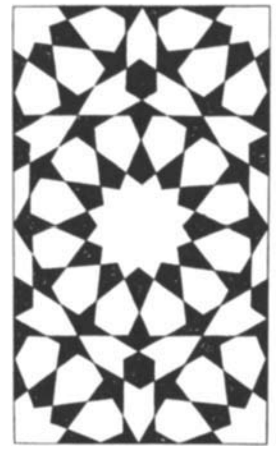


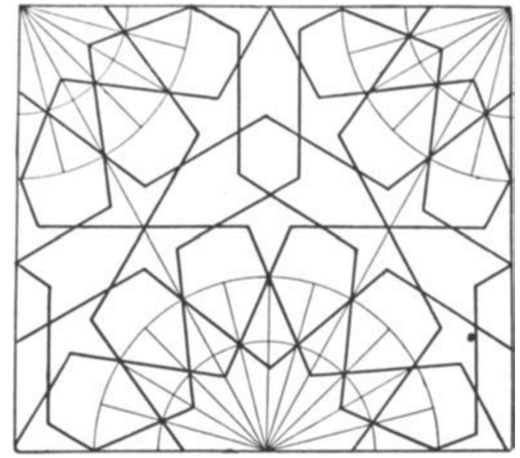
and arch elevations; these are missing from the Tashkent scrolls, which consist exclusively of ground plans, ground projections of vaults, and surface patterns. The muqarnas designs in the Victoria & Albert Museum are also quite elementary when compared to the earlier ones in Tashkent (cf. figs. 13–19, 29–30). The drawings in London are freehand and consist of weblike lines in black ink, occasionally highlighted in red; they no longer employ the complex color coding or stippling seen earlier. This may be explained by the relative standardization and simplification of muqarnas design in Qajar Iran.

A selected group of two-dimensional geometric patterns from the "collection of drawings made by Mirza Akbar, master-builder to the Shah of Persia in the early part of the nineteenth century" was first published in Archibald H. Christie's book on ornament, *Traditional Methods of Pattern Designing,* 1910, and later in Ernst H. Gombrich's *Sense of Order,* 1979. Christie observed that patterns formed by interlocking stars and polygons in the Mirza Akbar scrolls were generated by a series of concentric circles subdivided by rays, which formed complex constellations of radial symmetry (figs. 37–39). This method allowed Islamic designers to "recast familiar types of pattern by means of their newly discovered formula," giving them a distinctive appearance. Christie singled out such interlocking star-and-polygon patterns as "the most characteristic triumphs of Islamic ornamental invention," innovations that had relatively little influence on Western ornamental art. He concluded that "as the intricacies of these patterns were gradually mastered, each was reduced to a stereotyped formula, and passed from hand to hand until a collection of working drawings such as his [Mirza Akbar's] became a necessary part of the material equipment of every workshop."[49]

Clarke described the curious way in which such pattern scrolls were put together to record workshop practices. The ground plans were first worked out on a squared tracing board (probably resembling the one seen in fig. 6) by the master builder and then copied by his assistants onto squared paper to preserve them for future reference. Clarke's valuable account thus suggests that most of the drawings—glued together in no particular order in scrolls—would have accumulated as copies of executed or experimental designs:

> So well concealed are the methods used by oriental craftsmen to produce the work, which often puzzles us by its complexity, that travellers have been deceived into believing that by some intuitive faculty the Eastern master-builder is able to dispense with plans, elevations and sections, and start the foundations of the various parts of his structure without a precise predetermination of the bulk and requirements of the several parts. To all appearance the Persian master-builder is independent of the aid of plans. When engaged to build a house he first roughly levels the ground and then traces out the

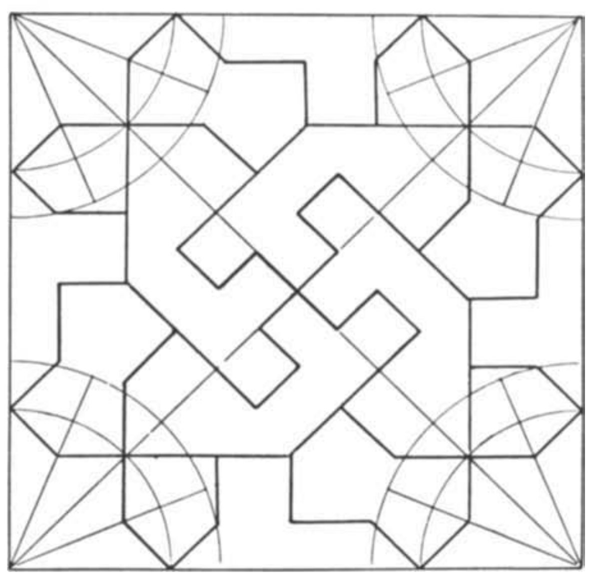




38a. Archibald H. Christie, drawing of a star-and-polygon pattern from the Mirza Akbar scrolls. From Christie 1929, 254, fig. 286. Photo: By permission of Oxford University Press.

38b. Archibald H. Christie, diagram showing the uninked radial grid lines of figure 38a. From Christie 1929, 255, fig. 287. Photo: By permission of Oxford University Press.

39a. Archibald H. Christie, drawing of a star-and-polygon pattern with a central swastika from the Mirza Akbar scrolls. From Christie 1929, 43, fig. 36. Photo: By permission of Oxford University Press.



39b. Archibald H. Christie, diagram showing the uninked radial grid lines of figure 39a. From Christie 1929, 268, fig. 306. Photo: By permission of Oxford University Press.

position of the walls (full size) with powdered "*gatch*" or plaster of Paris, apparently without other measurement than foot paces. Actually he has first of all worked out the general scheme, not as our architects do, on plain paper, but on a sectional lined tracing board, every square of which represents either one or four bricks. These tracing boards are the key to the mystery of their craft, and masons will understand the significance of the discovery that they represent in miniature scale the floor of the master-builder's workroom. . . .

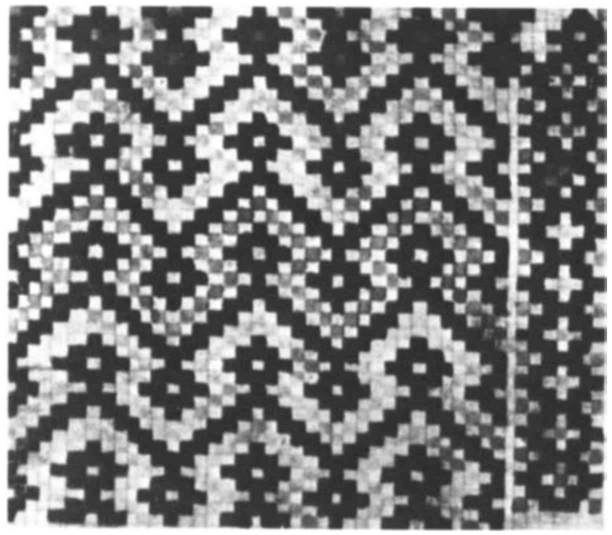
The surface is ruled both ways with fine lines parallel to the sides, like the sectional paper used by engineers. It is then protected by a coat of varnish, which allows the drawing to be washed off when done with. The system of planning is simple, as in Persia the bricks are square. A reed pen or brush is used to dot with Indian ink each small square which represents either one or four bricks, and when the design has been found to work out satisfactorily the squares are filled up with black and the plan is ready. It is then copied by an assistant on to similar squared paper and work is set out by laying bricks corresponding with those on the plan. Error is not possible, as the squares confine the sizes to brick dimensions, and as only one system of bond is used the number of bricks required for the intended structure is easily computed by counting the squares and multiplying by the height after deducting the openings. When transferred to paper for future references a curious custom is followed which bears the signs of great antiquity. These drawings are not kept separate nor bound as books, but are fastened together side by side with gum, like the Hebrew rolls of the Law, and are preserved in rolls which, when open, extend about 20 feet. . . . As a binding each roll terminates with a piece of leather cut in the form of a mason's apron with a string fastened to the peak. This string is long enough to wind several times round and thus secure it. Probably the survival of this early type of book is owing to the practical reason that a roll can be easily carried and concealed; as for the peculiar form of the leather binding it is a coincidence only due to the necessity of the case.[50]

Such design scrolls were identified by contemporary master builders in Iran and Iraq as *ṭūmār* (lit., "roll," or "scroll," vulgarized as *ṭmar*).[51] Clarke's comparison of them with the Hebrew "rolls of the Law" is particularly suggestive since they were vigilantly protected as canonical codes of craft practice passed on from one generation to the next. That the fragmentary Tashkent scrolls once had the same format is revealed by a leather

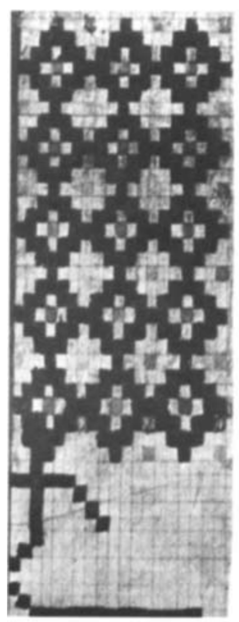
40. Ghulam b. Muhammad ʿAli, Qajar scroll fragment with repeat units for tile patterns, ca. 1800, ink, colors, and gold on paper. Photo: Courtesy Sotheby's, London.

flap preserved in one of the folders where they are now kept. The widespread use of such scrolls by Iranian master builders is confirmed by another surviving early nineteenth-century Qajar scroll with a brown morocco flap. It contains two-dimensional geometric patterns for architectural tiles signed by Ghulam b. Muhammad ʿAli (fig. 40). This fragmentary scroll sold by Sotheby's in 1985 to an unidentified private collector is reported to have measured 440 centimeters long and 12 centimeters high. The auction catalog describes it as having "margins ruled in colours and gold, one illuminated headpiece in colours and gold, imperfect at beginning and end."[52] As far as one can judge from its only available photograph, its geometric patterns contained in rectangular and square frames reinterpreted traditional motifs with a distinctive Qajar flavor.

Another Iranian *ṭūmār* was recently published in Tehran as twenty-four separate sheets of colored geometric patterns and square kufic calligraphy for *bannāʾī* brick masonry, executed on squared paper (figs. 41–44). Thought to be about a century old and identified by local practitioners as a collection of *girih-sāzī* (lit., "art of making knots") drawings (*ṭarḥ*), it belonged to a family of Shirazi master builders who inherited it from forebears going back a few generations. Though its two-dimensional patterns are rather simple, all of them based on checkered grids corresponding to modular brick shapes, the scroll testifies to the continuous use of traditional design methods in certain regions of Iran up to the modern era. The brief introduction



41. Geometric patterns for *bannāʾī* brick masonry drawn on a squared grid, Shiraz, probably nineteenth century, red and black ink and color (gray-green) on paper. From Khanlari 197[?], pl. 12.



42. Geometric patterns for *bannāʾī* brick masonry drawn on a squared grid, Shiraz, probably nineteenth century, red and black ink and color (gray-green) on paper. From Khanlari 197[?], pl. 18.

43. Geometric and calligraphic patterns for *bannāʾī* brick masonry drawn on a squared grid, Shiraz, probably nineteenth century, red and black ink and color (gray-green) on paper. From Khanlari 197[?], pl. 1.

44. Geometric and calligraphic patterns for *bannāʾī* brick masonry drawn on a squared grid, Shiraz, probably nineteenth century, red and black ink and color (gray-green) on paper. From Khanlari 197[?], pl. 2.

to the published Shiraz scroll facsimile lists the buildings recently restored in that city by local masters of *girih-sāzī;* among them it mentions a "*muqarnaṣ-band*" (lit., "muqarnas binder," or "muqarnas maker").[53]

The muqarnas therefore appears to have been a subcategory of the *girih* genre, which embodied both two- and three-dimensional patterns generated by similar geometric grid systems. The traditional Iranian master builder Asgar Shiʿrbaf classified both planar and spatial geometric patterns under the mode of design called *girih* or *kār-bandī* (knot work, work that binds, joins, and fastens together), terms referring to tightly interlocking systems of two- and three-dimensional geometric shapes governed by knotlike grids. In his book on this mode of design he pointed out that *girih*s could be applied to flat and curved surfaces alike in multiple media (including wood, plaster, tile, brick, and stone), and he classified both muqarnas and *yazdī bandī* (arch-net) vaults together with geometric surface patterns, executed by masters generically called *ustād-i kār-band* (master of knot work or joinery).[54]

The juxtaposition of planar and spatial geometric patterns in Islamic scrolls provides further evidence that the two were regarded as complementary systems. This remarkable connection has long been overlooked in the scholarship on Islamic architectural ornament, which has tended to focus on two-dimensional patterns and has viewed the muqarnas as an entirely separate category with puzzling origins. The hitherto unnoticed affinity between interlocking geometric surface revetments and the muqarnas opens new perspectives into the mysterious source of "stalactites"; they seem in fact to have originated as spatial *girih*s complementing the decorative use of the planar *girih* patterns with which they are often juxtaposed in scrolls as well as on buildings.[55] This connection—to which we shall return—supports Bulatov's observation that the direct translatability between two- and three-dimensional geometric patterns imbued Islamic architecture in Central Asia with a harmonious sense of unity, synchronizing the proportional systems of ground plans, surface revetments, and decorative vaulting. It is the fluid dialogue between planar and spatial geometry that explains the range of diverse pattern types compiled in scrolls.

Pattern scrolls similar to those described above have also been documented in modern Iraq, where once again they serve practicing traditional master builders who regard them as repositories of inherited craft secrets. One reference to these contemporary Iraqi scrolls interpreted the use of repeat units, often providing one-quarter of each design, as "a method to confuse those who were not members of the family of masons to whom the scroll belonged."[56] This element of secrecy, together with the transformation of traditional building methods by modern construction technologies (largely imported from the West), probably contributed to the disappearance of many earlier scrolls.

The surviving design scrolls in Iraq, Shiraz, London, and Tashkent demonstrate a remarkable continuity of architectural drafting methods in the brick-and-tile based architecture of Iraq, Iran, and Central Asia up to the modern era. This reflects the relative persistence of traditional construction methods; these were based on a brick core colorfully dressed with glazed bricks, tile work, plasterwork, and ornamental vaults, the compositions of which had gradually frozen into somewhat repetitive formulas in the post-Timurid era. With their spiraling foliage, curvilinear interlaces, and floral motifs, the serene surfaces of the celebrated late sixteenth- and seventeenth-century Safavid monuments of Isfahan did briefly move away from the predominantly angular geometry of the Timurid-Turkmen aesthetic, which the Uzbeks continued to perpetuate; but the geometric *girih* mode (more suited to standard brick-and-tile shapes) reimposed itself with a vengeance in the late Safavid and Qajar architecture of the eighteenth and nineteenth centuries. Surviving examples of Qajar scrolls testify to a revival of geometric patterning at a time when such patterns had come to be regarded by European Orientalists as the typical ingredients of Islamic architectural ornament (a subject to which we will turn in part 2).

The juxtaposition of ground plans with geometric designs for two- and three-dimensional architectural revetments in several surviving pattern scrolls reveals that they were compiled by master builders responsible for coordinating all stages of the design process in a building tradition that relied heavily on surface revetments. It may not be pure coincidence therefore that all the surviving

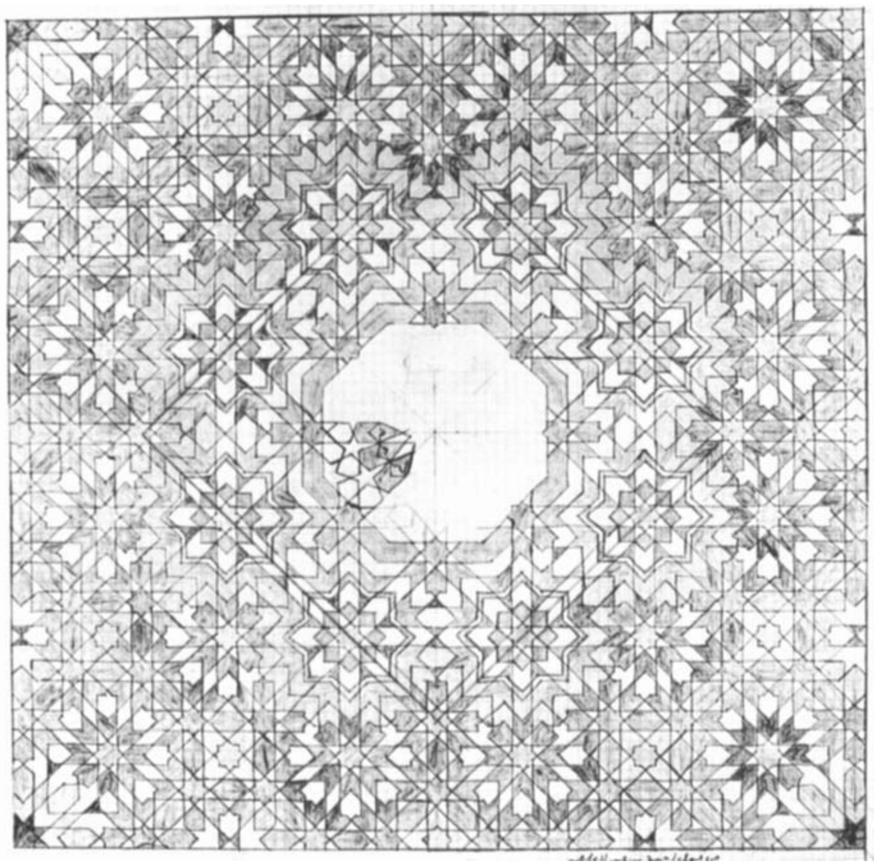
scrolls considered thus far belong to the same region, extending from Iraq and Iran to Central Asia, a region unified by a local tradition of brick-and-tile based architecture—a tradition that differed from the predominantly stone-based construction of neighboring Muslim states in Anatolia, Syria, Egypt, and India.

The only other known examples of comparable drawings survive in Morocco, another region characterized by a building tradition that relies on extensive polychromatic surface revetments of geometric tile work and woodwork, accompanied by elaborately carved stucco and stone with curvilinear vegetal interlaces and cursive inscriptions. This Maghribi tradition was originally inspired by architectural developments in the eastern Islamic world that had traveled westward between the eleventh and thirteenth centuries all the way to Spain. It underwent an internal development during the fourteenth and fifteenth centuries, which witnessed the flourishing of an intricate revetment aesthetic culminating in the Alhambra. Instead of exploring the sculptural articulation possibilities of stone, the local Mediterranean building material, the Maghribi aesthetic relied on continuous surface revetments, which carried the distant memory of the brick-and-tile based eastern Islamic architectural tradition. This tradition differed from the relatively more sober stone architecture of other Mediterranean-Islamic regions, such as Syria, Egypt, and Anatolia, in which ornamentation was sparsely used to articulate rather than veil architectural forms.

After the Christian reconquest of Muslim Spain, the so-called Hispano-Moresque architectural style persisted in Morocco up to the modern era without major innovations. Elaborate surface revetments conveying an impression of richness continued to conceal the simplicity of the basic architectural fabric, which underwent little structural development. In his *Le Maroc et l'artisanat traditionnel islamique dans l'architecture,* 1979 (translated into English as *Traditional Islamic Craft in Moroccan Architecture* in 1980), André Paccard demonstrated that in contemporary Morocco the engineer (*mouhendis,* i.e., *muhandis*), who supervises construction and acts as an intermediary between client and builder, does not design plans on paper for buildings but improvises their layout on the spot, tracing two rectangles (representing the outer wall and inner court) on the ground and subsequently determining the distribution of interior rooms according to the patron's wishes. The task of designing decorative patterns for surface revetments in multiple media falls to the master builders (*maalem,* i.e., *muᶜallim*), who continue to use paper drawings that record a body of inherited knowledge transmitted over the centuries from master to apprentice. Paccard noted the element of secrecy involved in this process—the masters "did not reveal all their secrets, which they guard jealously, transmitted as they are from father to son"—and added that the geometric grid systems used in generating various patterns were at the heart of this secrecy: "This refers to a sort of geometrical grid or pattern. From one and the same grid, all sorts of compositions can be made."[57]

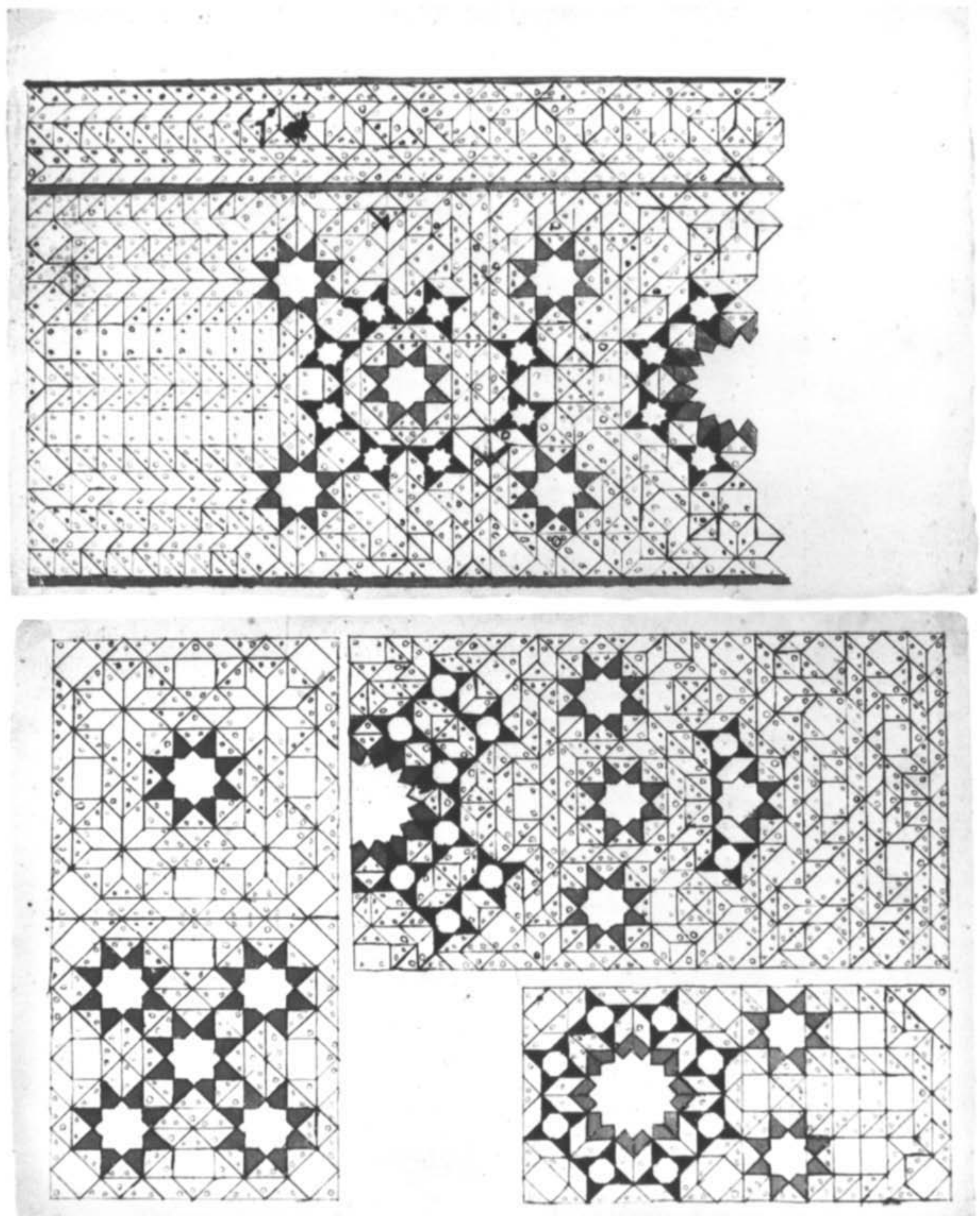
Paccard's monograph reproduces selected drawings of architectural ornament from the pattern books of practicing Moroccan masters, which included no ground plans. These design booklets (*daftar*) do not follow the traditional scroll format. Sometimes drawn on modern squared paper using colored pencils, they may be seen as updated versions of earlier scrolls, most likely created in response to an official effort to revive local artisanal traditions threatened by industrialization (figs. 45–50). In fact Paccard's book commemorates King Hassan II's architectural patronage aimed at revitalizing traditional crafts in Morocco, an undertaking that had actually commenced in the nineteenth century at the instigation of the French colonizers of North Africa.[58]

Even though the Moroccan pattern books betray some modern features, their traditional two- and three-dimensional geometric designs once again testify to the role of drawings in assuring the perpetuation of a mode of architectural decoration that dated back at least to the fourteenth or fifteenth century, if not earlier. No such drawings are known to have survived from Nasrid Spain (1230–1492), the architectural heritage of which was subsequently perpetuated in the Spanish Mudejar style and in Morocco. A carpentry manual entitled *Breve compendio de la carpintería de lo blanco y tratado de alarifes* (Brief outline of woodwork joinery and treatise on master builders), first published in Seville by the seventeenth-century Spanish carpenter and architect Diego López de

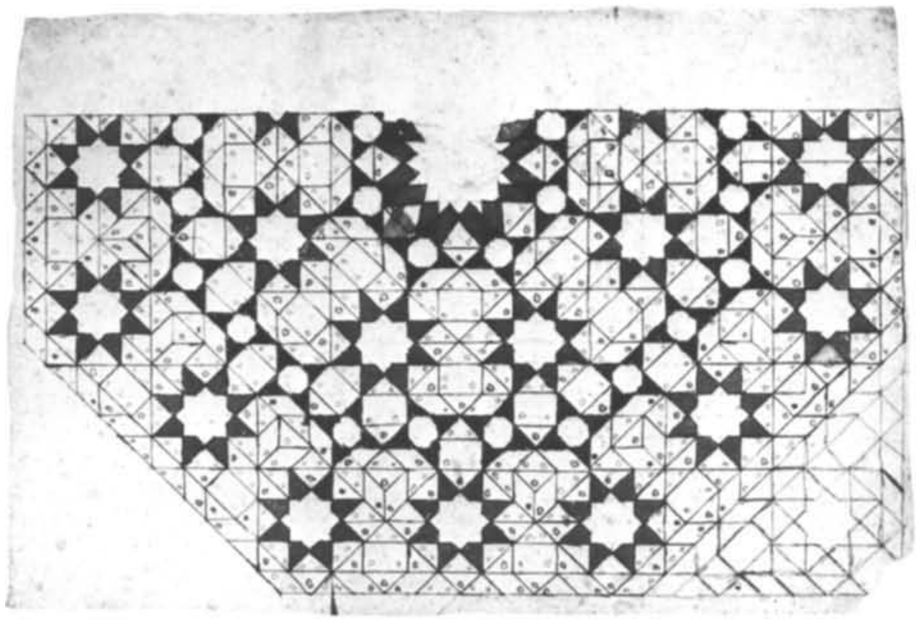


45. Moulay Hafid, star-and-polygon pattern drawn on squared paper, Morocco, twentieth century, ink and colored pencil on paper. From Paccard 1979, 1: 226, fig. 1.

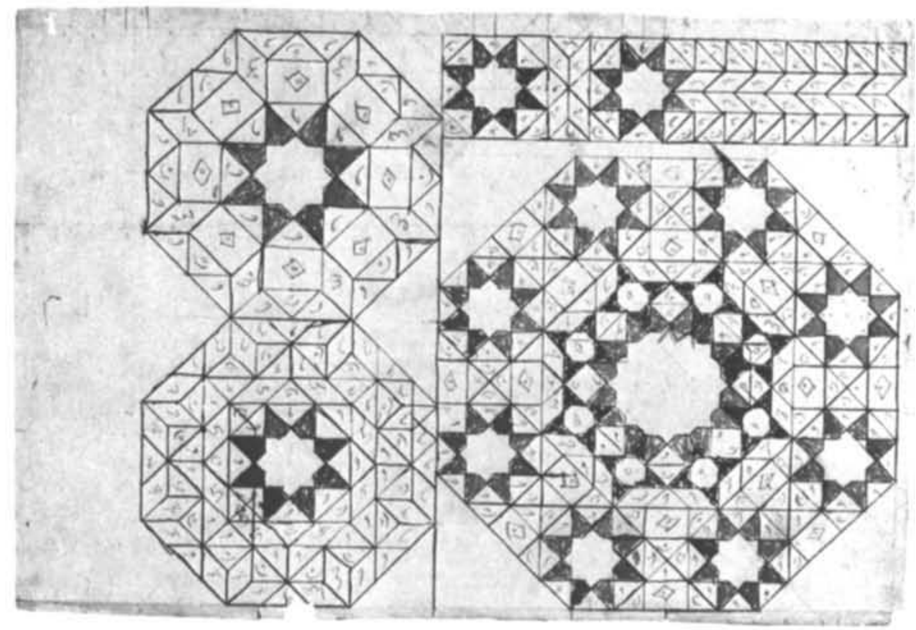
46. El Bouri, muqarnas vault patterns, Morocco, twentieth century, red and black ink on paper. From Paccard 1979, 1: 300, figs. 1, 2.

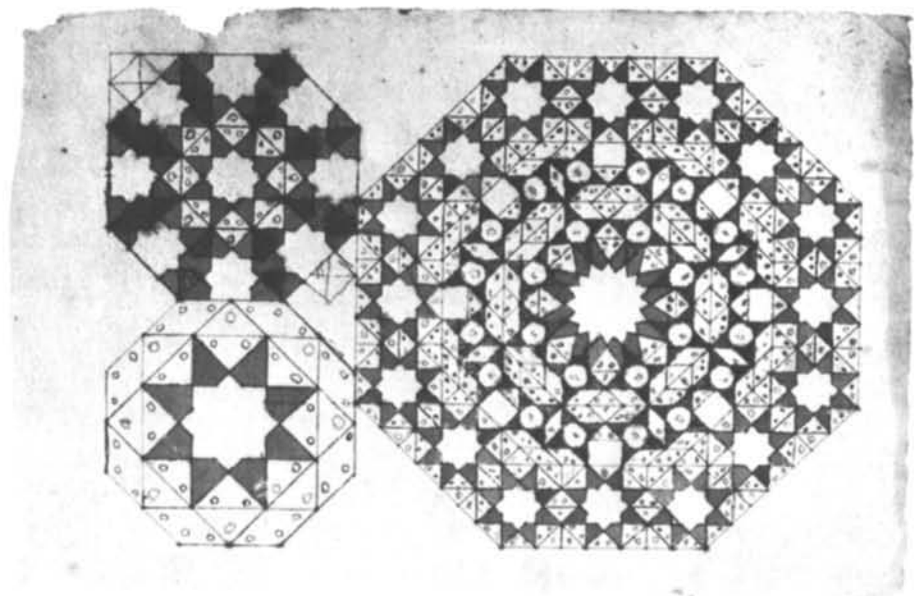


47. El Bouri, pattern for an octagonal muqarnas half vault, Morocco, twentieth century, red and black ink on paper. From Paccard 1979, 1: 301, fig. 1.

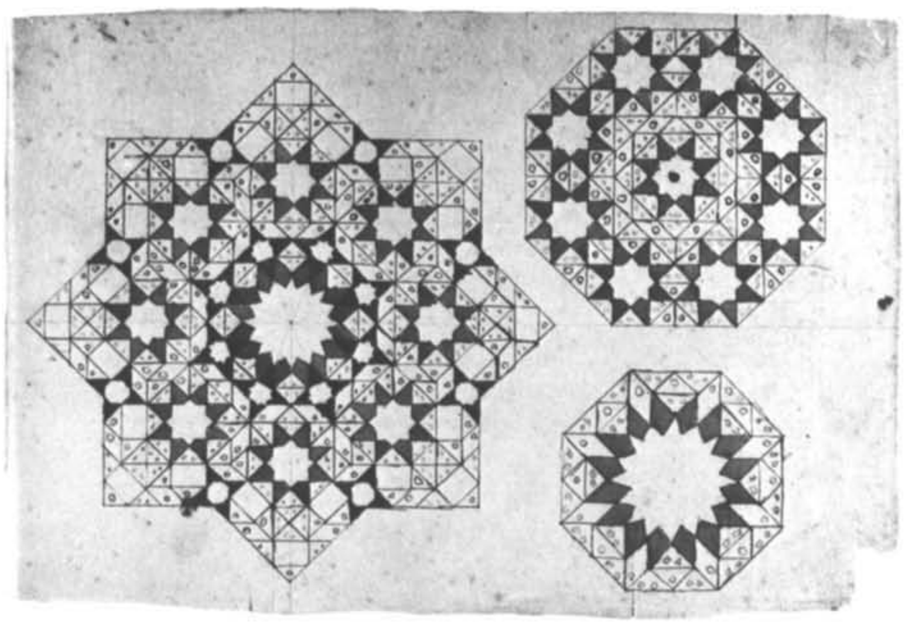


48. El Bouri, patterns for octagonal muqarnas vaults and the intrados of an arch, Morocco, twentieth century, red and black ink on paper. From Paccard 1979, 1: 296, fig. 1.

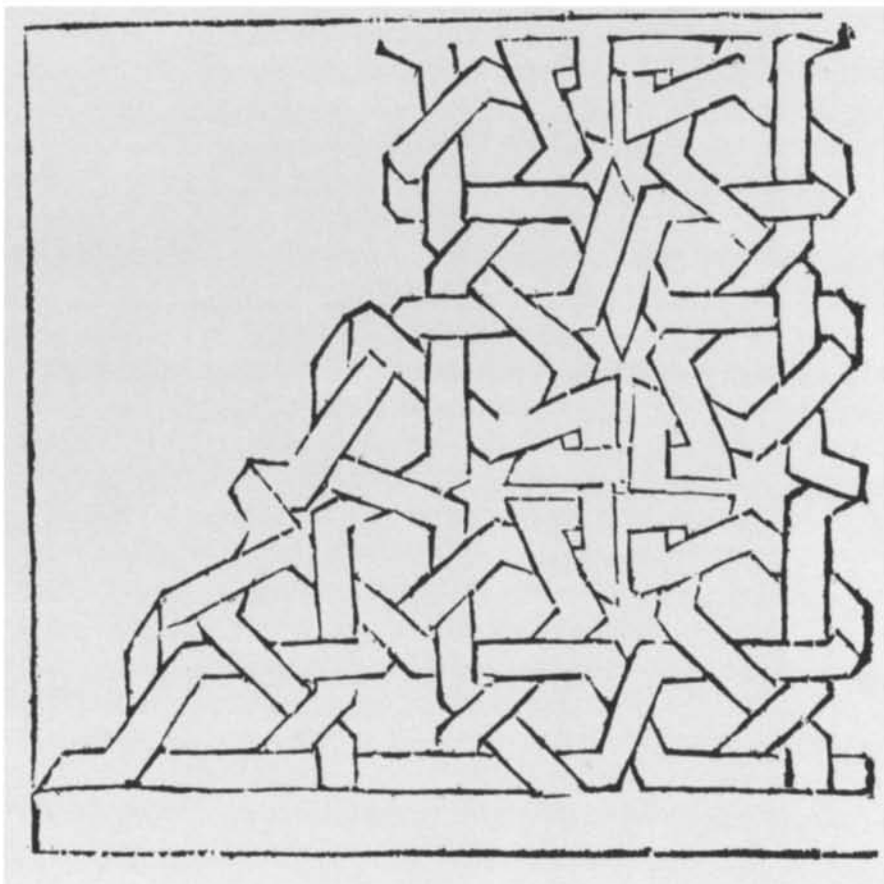




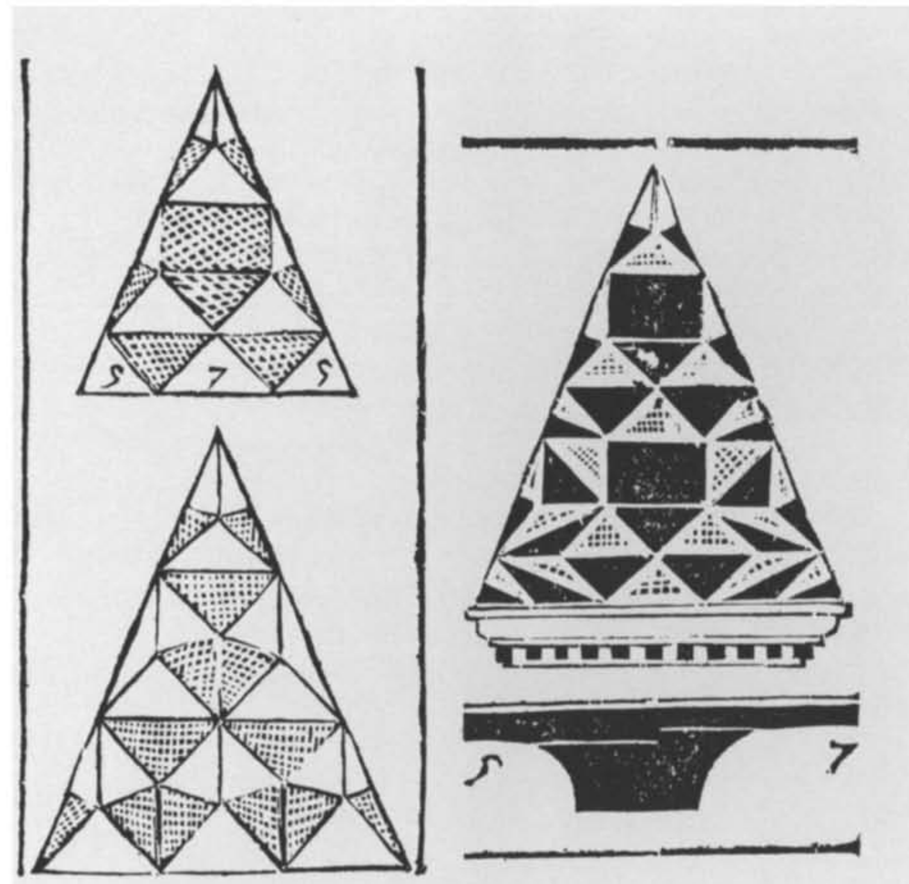
49. El Bouri, octagonal muqarnas vault patterns, Morocco, twentieth century, red and black ink on paper. From Paccard 1979, 1: 296, fig. 2.



50. El Bouri, patterns for octagonal and star-shaped muqarnas vaults, Morocco, twentieth century, red and black ink on paper. From Paccard 1979, 1: 296, fig. 3.



51. Diego López de Arenas, repeat unit for *artesonado* woodwork showing a strapwork pattern with interlaced stars and polygons. From López de Arenas 1912, fol. 14v.



52. Diego López de Arenas, triangular repeat units for wooden muqarnas vaults. From López de Arenas, fol. 23r.

Arenas in 1633, does, however, hint at the possibility that paper drawings may have been used in Muslim Spain as well. Condensed from a longer manuscript composed in 1619, this technical manual directly addressed carpenters and master builders. It provides two-dimensional star-and-polygon patterns for *artesonado* (paneled) woodwork applied to flat and curved surfaces and muqarnas vault projections, drawn with simple geometric methods using compasses and set squares (figs. 51, 52).[59] These drawings, which once again establish an intimate link between planar and spatial geometry, may well carry the traces of an earlier drafting tradition in Muslim Spain and the Maghrib.

The basic geometric grid systems used in the *daftar* of two-dimensional patterns by the modern Moroccan master Moulay Hafid are not so different from those seen in the *girih* scrolls of the eastern Islamic world. They testify to the often underestimated role of drawings in establishing a certain degree of visual unity among the distinctive local building traditions of distant countries. The three main types of grid systems used by this Moroccan master are square, isometric (triangular), and composite (polygonal). The most common composite type is based on the radial grid, that is, the circle divided into equal arcs by radii that generate interlocking star-and-polygon compositions used commonly in Maghribi tile work and woodwork.[60] Moroccan muqarnas projections also exhibit an uncanny similarity to those seen in scrolls from the east. The ground projections of wooden muqarnas vaults by the modern *maalem* el Bouri appear on elongated strips of cream-colored paper that could form a scroll if pasted together (see figs. 46–50). They are drawn in black ink, highlighted with red, and coded with small circles recalling those used in some of the Tashkent scrolls. El Bouri's drawings seem to carry the traces of much older graphic conventions, the roots of which are difficult to trace.

The relatively simple geometric compositions of el Bouri's muqarnas projections rely on a fixed vocabulary of eight modular units of sculpted wood arranged to form 45-, 90-, and 135-degree angles only (recalling the scheme scratched on the Takht-i Sulayman tablet [see fig. 1]). These compositions contrast with the infinite variety of angles seen in the more complex muqarnas quarter vault projections of the Tashkent scrolls, which are characterized by their increasing variety of stars and polygons. The simplicity of el Bouri's drawings—based on the square module—can be explained by the fact that muqarnas vaults fabricated from carved wooden units require a more rigid exactitude than their Timurid-Turkmen counterparts, which were often composed of flexible cast plaster units using the circle as a module.[61] The greater liberty of composition in the plaster muqarnas vaults of Morocco stemmed from their not being limited to 45-, 90-, and 135-degree angles.[62]

The standard patterns compiled in modern Moroccan sketchbooks indicate that the masters who drew them repeated inherited formulas rather than inventing new ones. Individual patterns and their constituent units were known by particular names, but the rules of proportion guiding their composition had been forgotten over time. Much like the practicing master builders of Central Asia at the turn of this century and those in contemporary Iran, the Moroccan masters repeated endless variations based on old geometric formulas, slightly modifying them by trial and error. In all these areas the individual components of traditional geometric patterns and their range of possible permutations became identified with a specialized vocabulary forming a common basis for communication among master builders and decorators specializing in various media, a vocabulary that also acted as a mnemonic device for pattern types recorded in scrolls.[63]

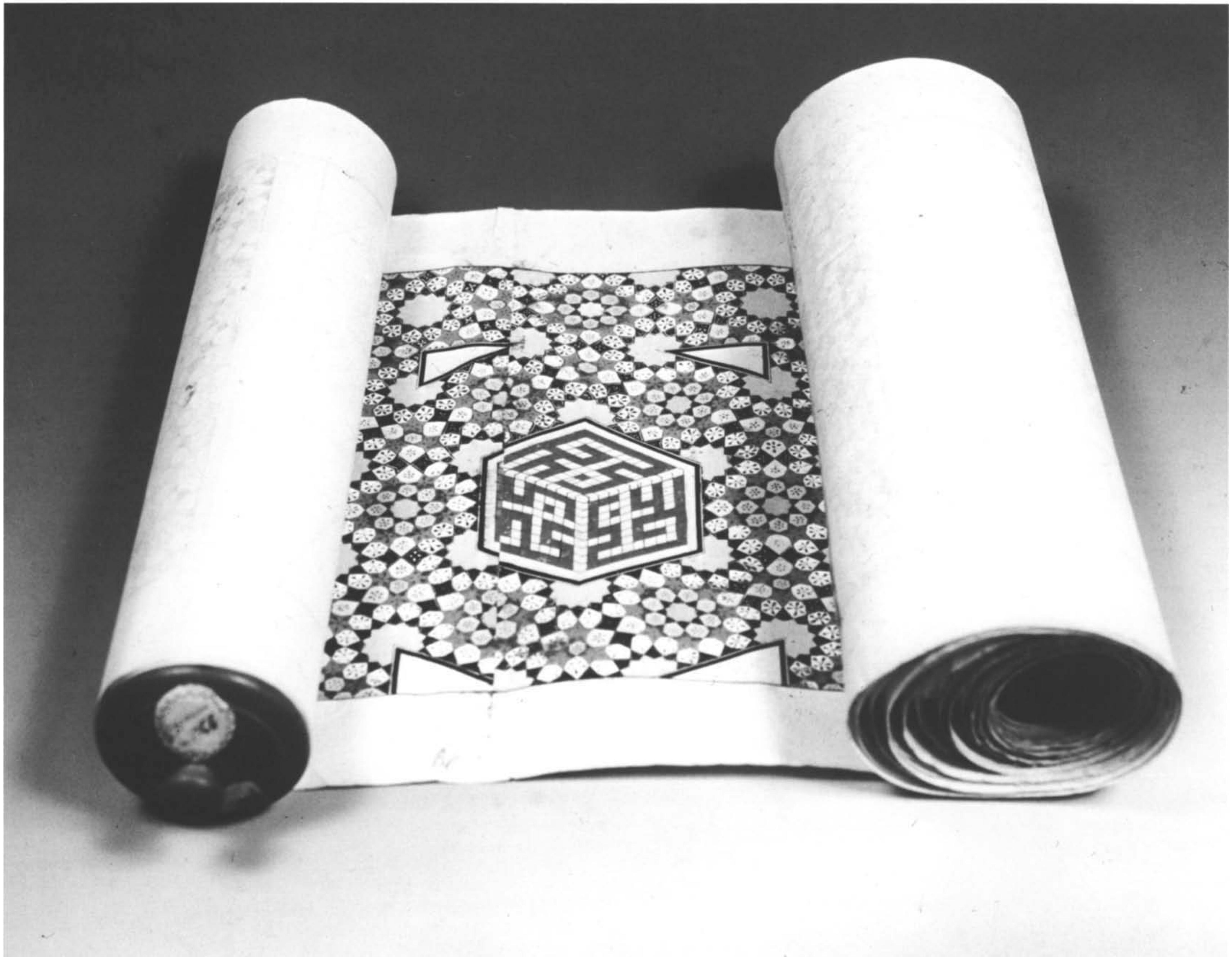
CHAPTER 2. THE TOPKAPI SCROLL, ITS DATE AND PROVENANCE

The Topkapı scroll is a typical *ṭūmār* pasted at one end to a wooden rod and at the other to a leather flap (fig. 53). It is 29.5 meters long and 33 to 34 centimeters high and contains 114 drawings in square or rectangular frames (cat. nos. 1–114). There is, however, no writing, date, or watermark that might point to when and where it was put together or how it entered the Ottoman imperial treasury collection. It combines two or more fragmentary scrolls of the same height, featuring two types of frames around the individual patterns; one of these is a thick black-ink frame that differs from its thinner counterpart (see cat. nos. 37, 40–114).

Pasted together in irregular fashion at some unknown date, the fragments of each scroll are glued together at various places, with points of rupture occurring between the drawings numbered 3–4, 27–28, 28–29, 36–37, and 39–40. Some of the drawings (see cat. nos. 4a, 28, 29, 37) are only partially preserved. Those numbered 3 and 27, on the other hand, are two halves of the same pattern, just like cat. nos. 36 and 39, indicating the haphazard way in which the scroll fragments were put together to form a single piece. Judging from Clarke's remark that Qajar scrolls were approximately 20 feet long, the impractical length of the Topkapı scroll (96.76 feet) can only be explained by its unprofessional restoration, most likely by the royal librarians of the Ottoman imperial treasury, who would not have been acquainted with this type of document.[64] The similarity of designs and graphic conventions in the fragments—each of which is drawn on the same type of heavy, high quality cream-colored rag paper—however, leaves little doubt that the combined scroll constitutes a consistent corpus, possibly from a single hand.

The scroll appears to have taken its present form after undergoing further repairs; the modern arabic numerals on its folios of various sizes must have been added when the manuscripts of the Topkapı Palace Museum Library were being cataloged. Its catalog number, Hazine (Treasury) 1956, indicates that it originally belonged to the imperial collection, once housed at the Inner Treasury in the third court of the Topkapı Palace. That architectural drawings were kept in that treasury is confirmed by an early inventory of its collection, compiled in 1505, which lists a chest full of working drawings (*kārnāme*), stored together with a brass architectural measuring stick 1 cubit long.[65]

The earliest known examples of Ottoman architectural drawings now kept in the Topkapı Palace Museum Archives seem to represent unapproved projects proposed to the sultan; this appears to be the most likely hypothesis since very few of these drawings correspond to extant buildings. The sultans were often presented with several alternative designs; one of the surviving examples shows three options for a mausoleum project on the same page with indications of comparative costs (see fig. 2a). When Süleyman I ordered the construction of the Şehzade mosque in Istanbul in 1543, architect-engineers (*mühendisān*) prepared plans and drawings (*resmler ve ṭarḥlar*) from which the sultan chose the one that appeared best proportioned (*mevzūn*) and most agreeable (*maṭbūʿ*).[66] It is probable that in such instances the rejected plans were placed in the Inner Treasury; the chosen drawing presumably would be returned to the chief architect for use. The Office of Royal Architects at the Vefa district in Istanbul had its own



53. Topkapı scroll, late fifteenth or early sixteenth century, ink and colors on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS H. 1956.

archive of plans, the contents of which appear to have disappeared without a trace.[67]

The earliest Ottoman ground plans at the Topkapı Palace Museum Archives are drawn on uninked squared grids and can be dated to the late fifteenth and early sixteenth centuries on the basis of their watermarked Italian paper (see figs. 2–4).[68] The use of Italian paper distinguishes them from the Topkapı scroll's unwatermarked heavy rag paper, which is of eastern origin. Moreover, the Ottoman plans are drawn on individual folios of different sizes rather than being pasted together in the scroll format so common in the Iranian world. These differences strengthen the probability that the Topkapı scroll was compiled somewhere in the east. This is further supported by the fact that the scroll's patterns were largely intended for a brick-and-tile based architecture foreign to the Ottoman tradition of stone masonry. Its drawings consist of geometric patterns and inscriptions on squared grids for *bannā'ī* brick masonry, two-dimensional star-and-polygon patterns, whole or partial projections of radial muqarnas or stellate arch-net vaults, and details of architectural ornament (see Catalog for a descriptive list of drawings). These drawings, which would have had little relevance in the Ottoman context, constitute the largest known repertory of two- and three-dimensional geometric patterns for Timurid-Turkmen or early Safavid architectural revetments.[69]

The provenance and date of the Topkapı scroll can be established by comparing it with other known Islamic scrolls, by assessing the relationship of its designs with extant architectural monuments, and by the circumstantial evidence of its preservation in the Ottoman imperial treasury collection. First let us compare it to the scrolls previously described. In terms of its paper size the Topkapı scroll (33–34 cm high) is most closely related to the two fragmentary sixteenth-century Tashkent scrolls drawn on 38-centimeter-high Samarqandi paper; all known examples of later scrolls consistently use paper of a lesser height. The Topkapı scroll's sophisticated graphic conventions and design vocabulary also find their closest parallel in the Tashkent scrolls, even though the former scroll does not contain any ground plans. The now-lost parts of the fragmentary documents that make up the Topkapı scroll may, however, have included ground plans, or perhaps other scrolls with ground plans originally complemented those segments that have survived. The complexity of graphic conventions used in the Topkapı scroll certainly points to an earlier date of compilation than the nineteenth- and twentieth-century scrolls discussed above, which contain rather sketchy drawings displaying an eclectic design vocabulary incompatible with an early date.

The Topkapı scroll's geometric patterns are generated by various grid systems and drawn with a reed pen in black ink; many of them are highlighted with red ink and sometimes with a wider range of colors including blue-gray, pink, orange, yellow, and green. Multiple colors and stippling in red or black ink are used as a graphic convention to differentiate the individual components of complex designs, to code their symmetric properties, or to distinguish the superimposed tiers of muqarnas projections. The underlying geometric grids or construction lines of the patterns in the Topkapı scroll were first incised on the paper with a metal point. Only the simpler square and triangular grids, characterized by their static symmetry, were traced over in black ink. The dynamically symmetrical composite radial grids are made up of constellations of weblike concentric circles subdivided into equal arcs by shared radii; they were probably made by using compasses provided with one scoring point, and they remain uninked, "dead" drawings lightly scratched on the surface of the paper so as not to detract from the inked patterns they generate (see the overlay drawings, which simultaneously present the "dead" drawings and the inked patterns, in the Catalog). These radial grids, often complemented by other superimposed geometric schemes and oriented along dynamic axes of symmetry, exploit the two fundamental harmonic systems of lines provided by the circle: spokelike straight lines radiating from various centers and curved concentric circumferences that successively limit the progressive extension of circular space.

The Topkapı scroll's drawings often consist of repeat units meant to be multiplied by symmetry. They are all geometric patterns generated by three types of grid systems: squared, triangulated, and composite radial (polygonal). The first two are only used for two-dimensional surface patterns and calligraphy, intended for the most part for transfer to *bannā'ī* brick masonry but also adapt-

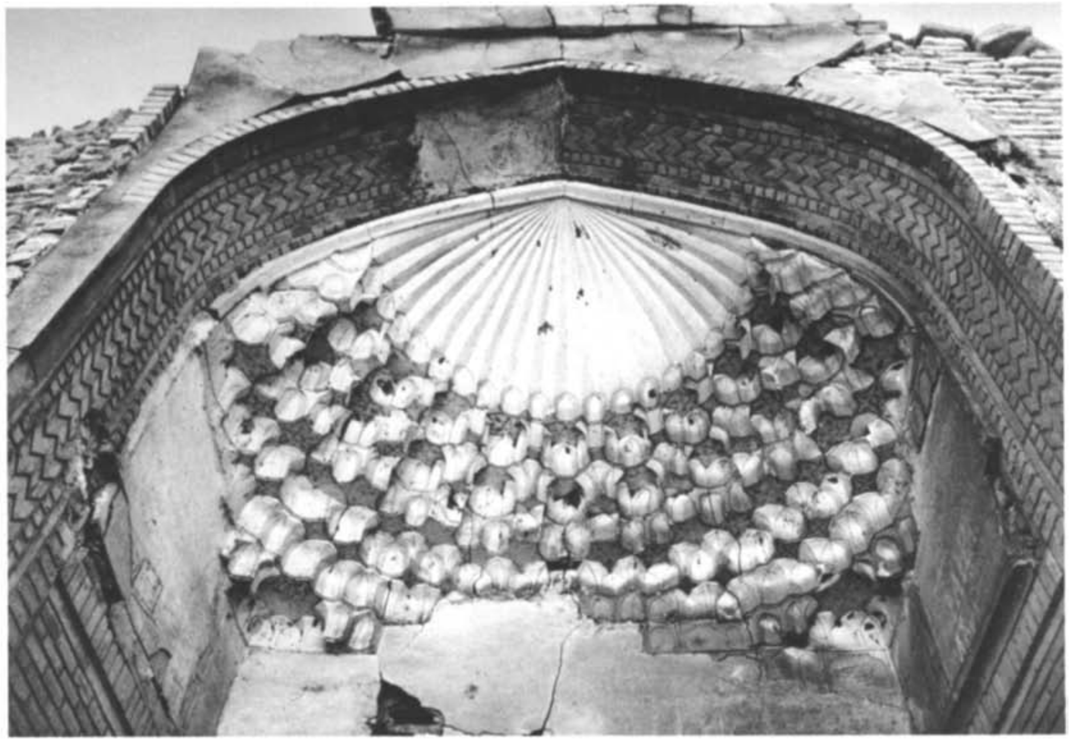
able to other media such as wood, stone, painted plaster, or mosaic and inset tile work (see Catalog, Groups I, II). They are far outnumbered by the more complex designs based on composite radial grids, which were used for both two- and three-dimensional patterns (see Catalog, Groups III, IV). This predominance of the radial grid, which finds a parallel in the Tashkent scrolls, is in keeping with Bulatov's observation that late fifteenth-century Timurid designers and their successors had come to favor radial symmetries in two- and three-dimensional architectural revetments.[70]

The numerous ground projections for muqarnas vaults contained in the Topkapı scroll are strikingly similar to those included in the Tashkent scrolls, in terms not only of the radially symmetrical type of muqarnas depicted but also of the conventions for representing multiple planes on a flat surface (see Catalog, Group IV.ii). These drawings represent parallel projections (mirror or orthogonal projections) of three-dimensional muqarnas tiers where points on the flat picture plane correspond to multiple layers in space. In them the boundary lines of successively corbeled muqarnas tiers, representing different spatial levels collapsed onto the same drawing, are often highlighted with stippling or color coding. Only in a few cases are the muqarnas projections of the Topkapı scroll rendered in simple black line drawings. Whether rendered in black-ink outlines, color coded with red and black ink, or highlighted with stippling, these muqarnas drawings use sophisticated graphic conventions reminiscent of the Tashkent examples—the only real difference being that the latter sometimes use a wider range of colors, including yellow, orange, and green, in addition to stippling. The black-and-red color scheme used in the Topkapı scroll is also seen in the much simpler muqarnas drawings of Mirza Akbar and el Bouri.

Like their counterparts in Tashkent, the Topkapı scroll's muqarnas projections are composed of radially organized tiers with a wide variety of polygons and stars interlocking at many different angles. Such radially composed plaster muqarnas vaults emanating from fluted shell-shaped or fan-shaped semidomes had displaced the simpler orthogonal type in the Iranian world by the second half of the fifteenth century. Lisa Golombek and Donald Wilber have identified the radially symmetrical muqarnas with the "Shirazi" type that the Timurid astronomer and mathematician Ghiyath al-Din Jamshid Mas'ud al-Kashi (d. 1429) described as the most complex variant of the four basic muqarnas types known to him (see "The Muqarnas" in the present volume).[71] The first three types were orthogonal, based on the modular use of the square; only the Shirazi muqarnas was generated by radial grid systems. It promised an almost unlimited range of possible combinations of polygons and star polygons fitted together at many angles along a network of concentric circles. The majority of the muqarnas vault projections included in the Tashkent and Topkapı scrolls represent this type of radial muqarnas, commonly used from the late fifteenth century onward.

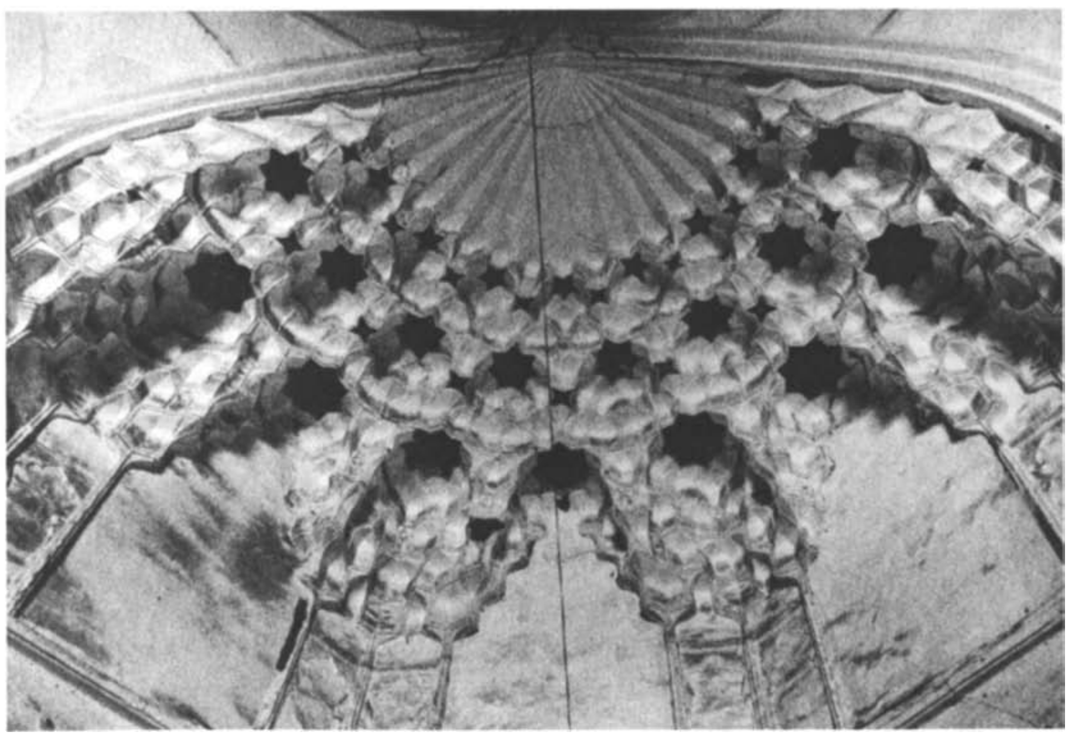
The Shirazi type of muqarnas seems to have spread to the east from Iran. Although only a few fifteenth-century Timurid-Turkmen buildings with this muqarnas type have survived in Iran itself, examples are widely encountered in the Uzbek monuments of Central Asia, such as the sixteenth-century Chahr Bakr shrine complex in Bukhara (figs. 54, 55). The muqarnas semidome of the mihrab iwan at the Taqi al-Din Dada shrine (1473–1474) in Bonderabad—located thirty-six kilometers northwest of Yazd—is an early variant of the Topkapı scroll's radial muqarnas patterns emanating from fan-shaped semidomes. The muqarnas superstructure of this mihrab (fig. 56) features a series of four-, five-, seven-, and eight-pointed stars in tile mosaic, set into tiers of plaster. The fluted type of radial muqarnas pattern emanating from a conch- or shell-shaped semidome, which often appears in the Topkapı scroll, is encountered in the Masjid-i Muzaffariya (Blue mosque, 1465), the only major Turkmen monument surviving in Tabriz. This muqarnas type is translated in simplified form into stone on the fifteenth-century muqarnas portals of the Shirvan Shahs complex in Baku, located to the north of Tabriz.[72]

The Topkapı scroll's muqarnas patterns and its typically Timurid-Turkmen design repertory seem to point to a late fifteenth- or sixteenth-century date of compilation. Its patterns appear to have been created at a time when the international Timurid geometric design vocabulary (perpetuated in the Turkmen and early Safavid courts of Iran and in the Uzbek court of Central Asia) was still very much alive. It may, of course, be that the



54. Plaster muqarnas hood of a portal, Chahr Bakr shrine complex, Bukhara, 1559–1569. Photo by author.

55. Plaster muqarnas hood of a portal, Chahr Bakr shrine complex, Bukhara, 1559–1569. Photo by author.



56. Plaster muqarnas mihrab hood inlaid with mosaic tile-work stars, Taqi al-Din Dada shrine complex, Bonderabad, 1473–1474. From Golombek and Wilber 1988, 2: fig. 354. Photo: Courtesy Renata Holod.

57. Muqarnas cornice of the ribbed dome, madrasa complex of Gawhar Shad, Mashhad, 1432. Photo: Donald Wilber, courtesy of Asian Art Photographic Distribution, Ann Arbor, MI.

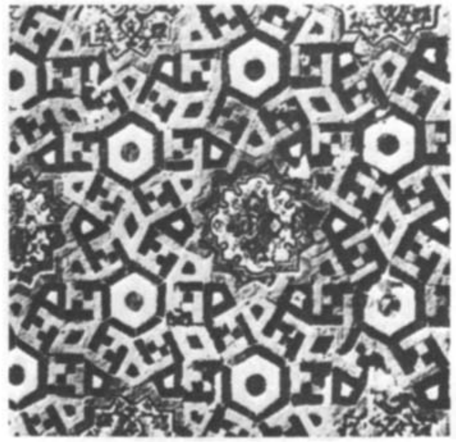
58. Detail of composite kufic inscription panel in *bannā'ī* brick masonry, side portal of the Masjid-i Jami^c, Varzana, 1442–1444. Photo: Courtesy Anthony Hutt, Scorpion Archives.

scroll's Timurid-Turkmen repertory was copied at a much later date, but this is quite unlikely given the striking difference between its sophisticated drafting conventions and those of nineteenth- and twentieth-century scrolls. The fragmentary documents that compose the Topkapı scroll have been damaged over time, and this also seems to suggest an early date. If the scroll were a recent copy of an older document, it would not feature so many breaks but instead would be consistently designed and rationally ordered. The absence of anachronistic motifs inconsistent with an international Timurid-Turkmen design vocabulary further argues for the late fifteenth- or sixteenth-century date that Filiz Çağman assigns to the Topkapı scroll on the basis of her long experience with comparable documents in the Topkapı Palace Museum Library's manuscript collection.[73]

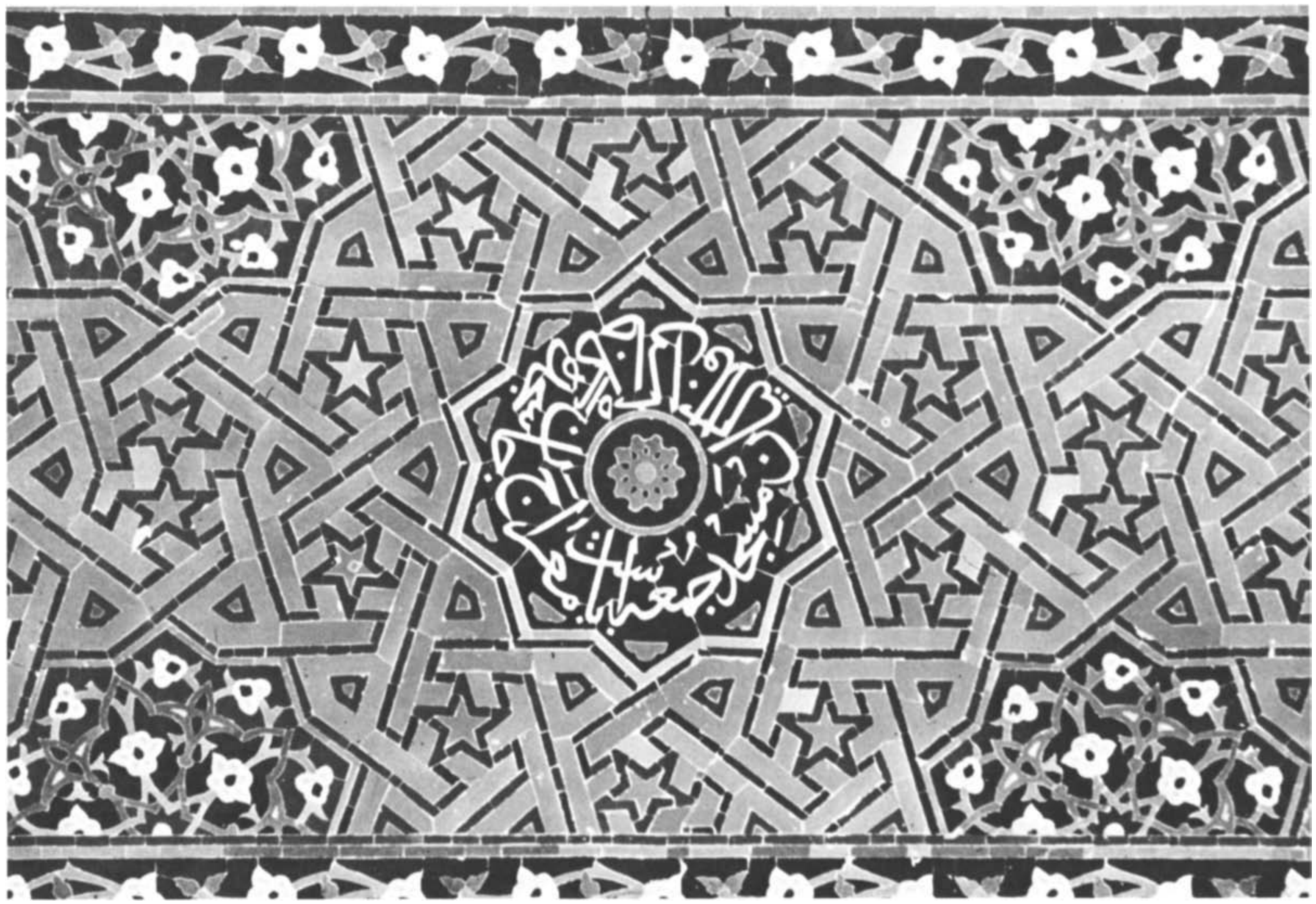
Let us now briefly compare the Topkapı scroll's patterns with those observed in extant Timurid-Turkmen monuments. As has been previously noted, the former—largely foreign to the Mediterranean stone masonry tradition of Ottoman architecture—were no doubt intended for a brick-and-tile based building tradition relying on extensive polychromatic surface revetments. Most of them would have had little relevance in the Ottoman context; in this category fall patterns for the muqarnas cornices of typically Timurid ribbed domes (fig. 57, cat. no. 81), for arch-net and plaster muqarnas vaults, for *bannā'ī* brick masonry, and for mosaic tiling. Only a few of the Topkapı scroll's drawings, however, can be directly linked with extant Timurid-Turkmen monuments, suggesting that the patterns represent a workshop catalog of available design choices rather than sketches prepared for specific buildings. Nonetheless, many generic similarities exist between the scroll's ideal pattern types and those encountered in the remaining architectural monuments of the broadly defined international Timurid-Turkmen cultural sphere. The most exact parallels seem to point to western and central Iran during the second half of the fifteenth century, even though many of the scroll's patterns do originate in Seljuq-Ilkhanid prototypes that continued in use in the post-Timurid era.

Geometric and calligraphic patterns drawn on squared grids for use on *bannā'ī* brick masonry represent a well-defined group in the Topkapı scroll; their variants are widely used in many Iranian and Central Asian buildings (see Catalog, Group I). Among these patterns is a composition for a square kufic panel (see cat. no. 72). It finds almost an exact replica on the entrance portal of the Masjid-i Jami^c in Varzana (located on a caravan route between Isfahan and Yazd), which is dated 1442–1444 and associated with the Timurid ruler Shahrukh (fig. 58), who reigned from 1405 to 1447.[74]

Two-dimensional interlocking star-and-polygon compositions intended mainly for mosaic tile work and carved plaster constitute another common pattern type in the Topkapı scroll (see



59. Mosaic tile panel, Masjid-i Jami^{c}, Varamin, fifteenth century. Photo: Courtesy Nader Ardalan.

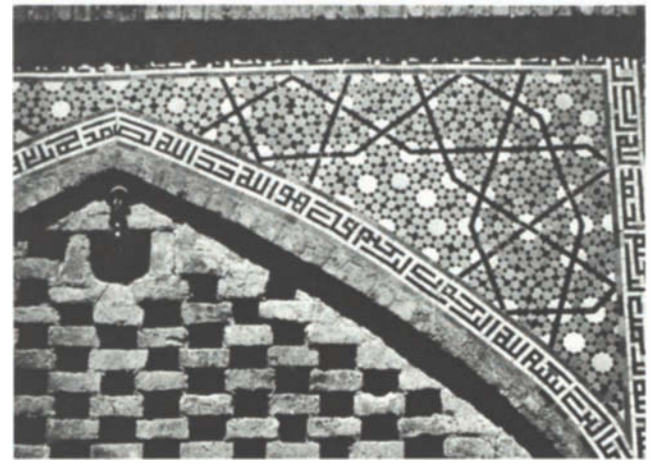


60. Mosaic tile dado panel in the vestibule behind the entrance iwan, Masjid-i Jami^{c}, Yazd, fifteenth century. Photo: Courtesy Harvard University, Fogg Art Museum, Fine Arts Library, Visual Collections.

Catalog, Group III). A distinctive aspect of these patterns is their rigidly angular character (the exception is a single curvilinear design at the very end of the scroll [see cat. no. 114]). This is a factor entirely in keeping with the Timurid-Turkmen geometric design repertory, which had conspicuously moved away from the curvilinear interlaces encountered in earlier monuments. Once again the closest parallels for this pattern type appear in extant Timurid-Turkmen buildings. One of the Topkapı scroll compositions in this category is strikingly similar to a mosaic tile panel at the Masjid-i Jami^{c} in Varamin, which was restored in the reign of Shahrukh (cf. cat. no. 70, fig. 59).[75] Another pattern (see cat. no. 8), which provides the repeat unit for a mosaic tile panel, closely resembles the star-and-polygon composition on a fifteenth-century dado panel at the entrance portal of the Masjid-i Jami^{c} in Yazd and on the minbar of the nearby shrine complex of Taqi al-Din Dada in Bonderabad (fig. 60).[76]

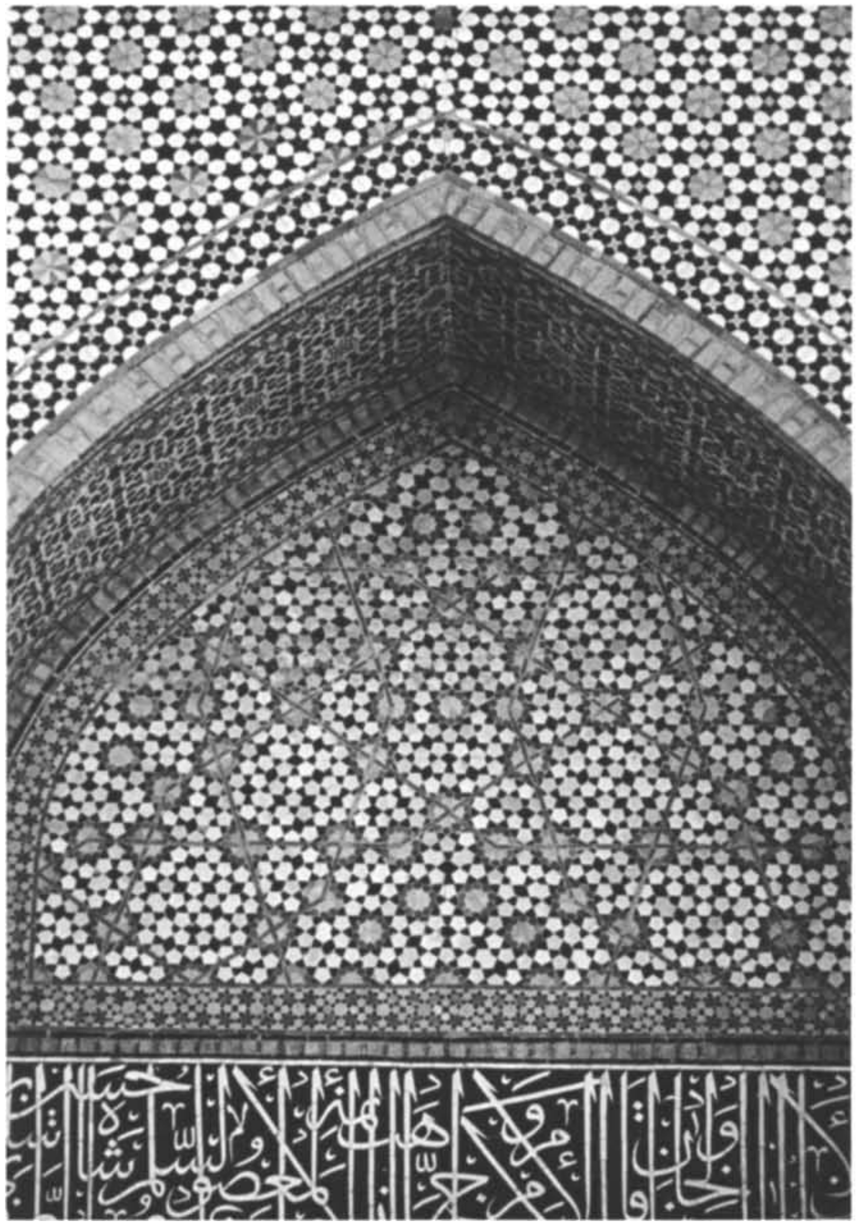
The Topkapı scroll's intricate patterns with three different types of stars (see cat. nos. 35, 39, 44) also find their counterparts in fifteenth-century mosaic tile and carved plaster compositions.[77] Another pattern type in the scroll consists of two superimposed star-and-polygon designs (see cat. nos. 28, 29, 31, 32, 34). Mosaic tile patterns belonging to this type appear in the Darb-i Imam at Isfahan (1453–1454), built by a governor during the reign of the Qaraqoyunlu ruler Jahanshah (figs. 61, 62).[78] In this type a background pattern

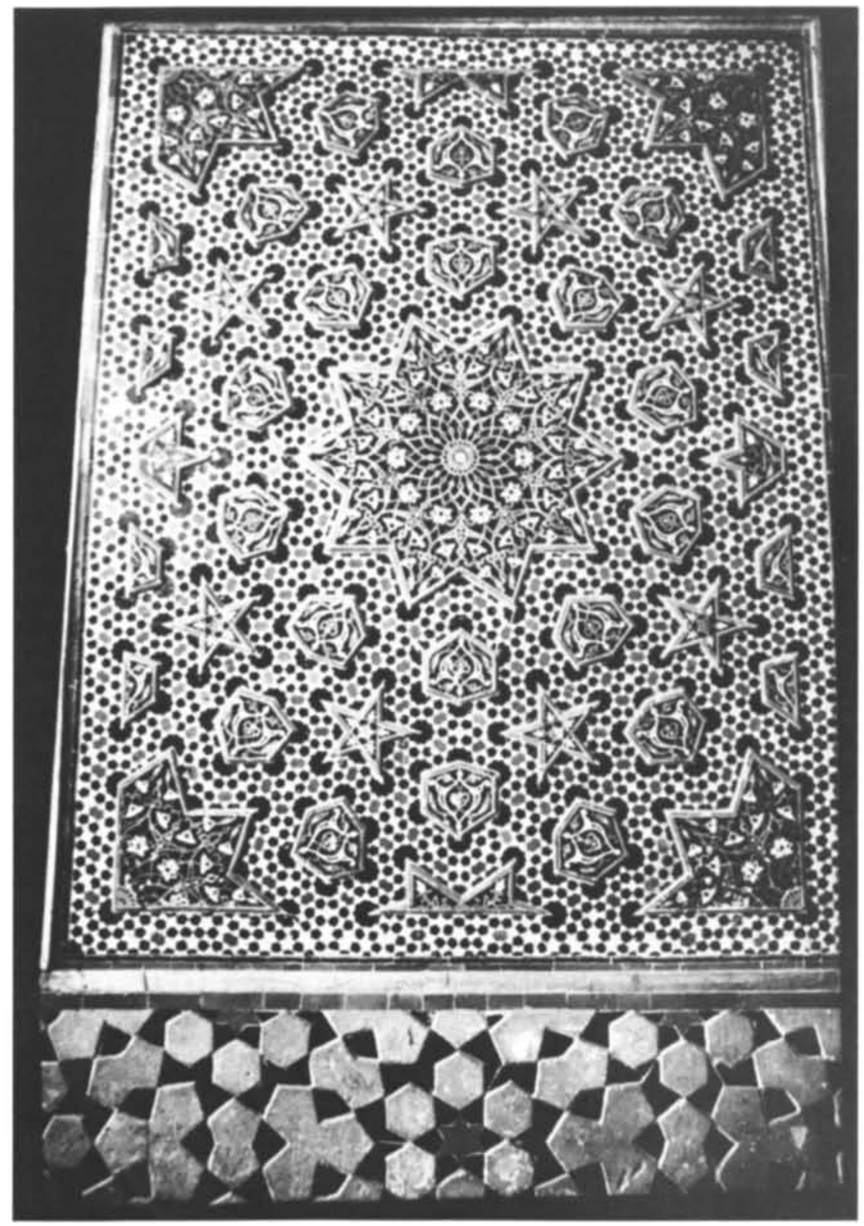
61. Mosaic tile work on an arch spandrel, Darb-i Imam, Isfahan, 1453–1454. Photo: Courtesy Kendall Dudley.

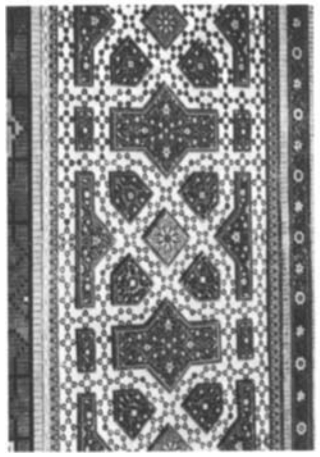


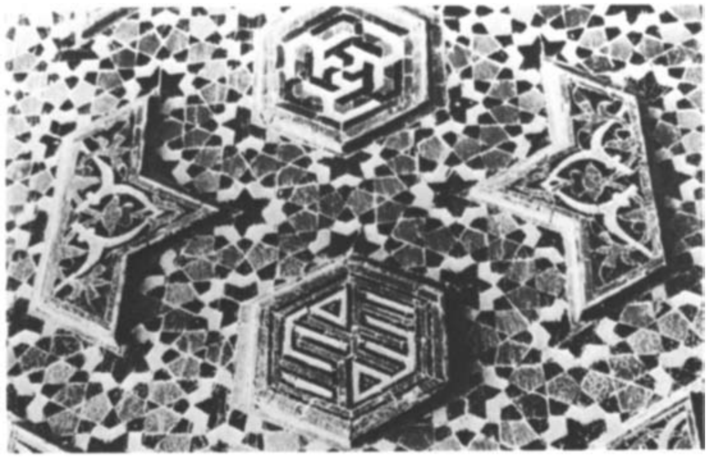
62. Mosaic tile work on a portal, Darb-i Imam, Isfahan, 1453–1454. Photo: Courtesy Kendall Dudley.

63. Double-layered relief mosaic tile panel at the side of the north portal, Darb-i Imam, Isfahan, 1453–1454. From Golombek and Wilber 1988, 2: pl. xva. Photo: Courtesy Lisa Golombek.









64a. Double-layered relief mosaic tile panel, Masjid-i Jami^c of Gawhar Shad, Mashhad, 1416–1418. From Golombek and Wilber 1988, 2: pl. xiia. Photo: Courtesy Lisa Golombek.

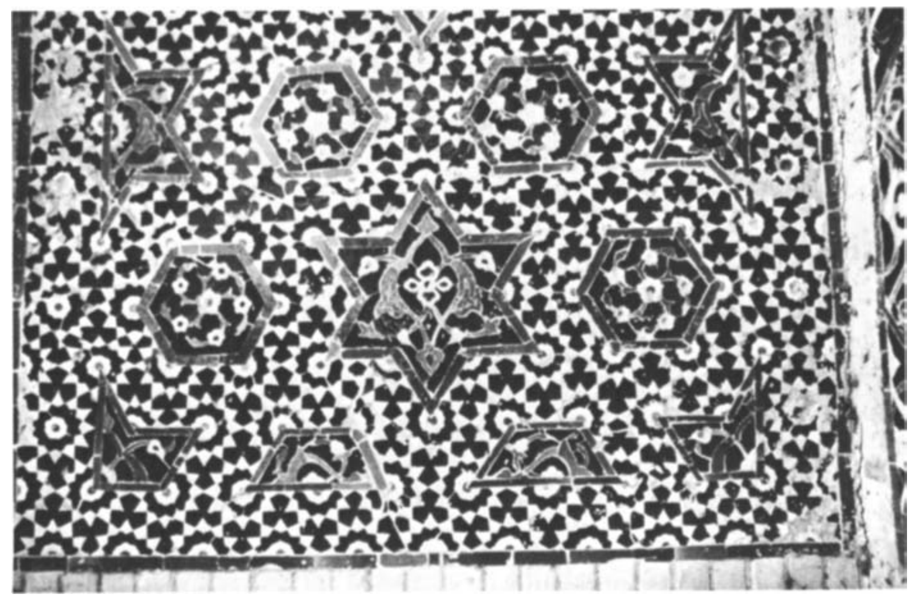
64b. Detail from double-layered relief mosaic tile work on the soffit of the arch leading into the dome chamber, Masjid-i Jami^c, Varzana, 1442–1444. Photo: Courtesy Anthony Hutt, Scorpion Archives.

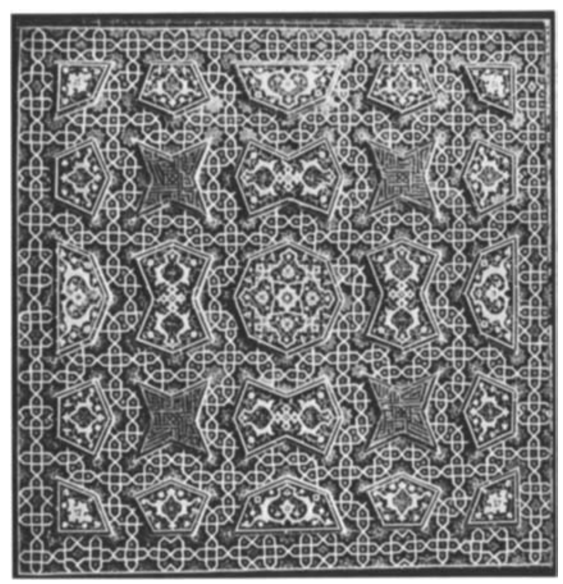
composed of small interlocking stars and polygons is superimposed with a linear pattern delineating large stars and polygons proportionally related to the background motifs in such a way that its nodal points of intersection overlap with the centers of some background stars.

The Darb-i Imam also features mosaic tile panels with large polygon and star fragments superimposed on a minutely rendered background composed of small interlocking stars and polygons (fig. 63). These panels find their parallels in two Topkapı scroll drawings (see cat. nos. 38, 49), which once again display a remarkable ingenuity in manipulating proportionally related background and foreground motifs in different scales. The drawings represent, in fact, a tour de force of superimposed geometric schemes exemplifying the complex interplay of two complementary layers of pattern and are thus perhaps comparable to polyphony in music. In them the corners of the large foreground motifs raised in relief, which would form a continuous field if joined together, fall on the centers of some background stars. Comparable examples of mosaic tile panels exhibiting this rare Timurid-Turkmen technique of relief tiling appear on the sanctuary iwan of the Masjid-i Jami^c of Gawhar Shad in Mashhad (fig. 64a), built for Shahrukh's wife in 1416–1418, and on the Masjid-i Jami^c in Varzana (fig. 64b).[79] A similar composition appears in the mosaic tile work of the Darb-i Kushk in Isfahan (1496–1497) built by the son of the Aqqoyunlu ruler Uzun Hasan (fig. 65). Here, however, the mosaic tiles are executed in a single layer, not two, with large polygon and star fragments embedded in a field of smaller interlocking stars and polygons, signaling a loss of technical sophistication.

With a few exceptions from the Safavid period this unusual relief tiling technique and the distinctive pattern type associated with it seem to have largely disappeared after the late fifteenth century. The rare Safavid examples seen at the courtyard iwans of the Masjid-i Jami^c in Isfahan (fig. 66) and the shrine of Imam Riza in Mashhad have simpler background compositions than the Timurid-Turkmen examples, which are closer to the two drawings in the Topkapı scroll (see cat. nos. 38, 49). This resemblance supports the early date that I have proposed for the Topkapı scroll as well as its Iranian provenance, given that such relief tiles are uncommon in Central Asia. Other characteristics of the scroll also point to a closer kinship with the monuments of Iran than with those of Central Asia. One of these is the frequent appearance of the rotated names *ʿAlī* and *Muḥammad* in its calligraphic compositions (see cat. nos. 71, 76, 91). Such inscriptions, so common in Iran with its Shi^ci sympathies, only rarely appear in Timurid and post-Timurid buildings further to the east. Popular in Iranian monuments from at least the Ilkhanid period onward, calligraphic compositions bearing the name *ʿAlī* also figure prominently in the nineteenth-century Qajar pattern scrolls (see figs. 31–33, 44).

The Topkapı scroll was probably compiled in the late fifteenth or sixteenth century somewhere





65. Mosaic tile panel at the portal, Darb-i Kushk, Isfahan, 1496–1497. Photo: Courtesy John Rosenfield.

66. Double-layered relief mosaic tile work at the southwest iwan in the courtyard, Masjid-i Jami^c, Isfahan, restored 1475–1476. The tiles may have been added in the early Safavid period, sixteenth century. From Seherr-Thoss 1968, 193, pl. 87. Photo: Hans C. Seherr-Thoss.

in western or central Iran, possibly in Tabriz, which served as a major cultural capital under the Ilkhanids, the Qaraqoyunlu, and the Aqqoyunlu Turkmen dynasties, as well as the early Safavids. Its geometric designs in all likelihood were produced under Turkmen patronage, but an early Safavid date is also a possibility as the international Timurid heritage would still have been very much alive. With the political decline of the Timurids in the east around the middle of the fifteenth century, the initiative in architectural patronage had returned to western Iran. The Topkapı scroll seems to have been put together after that point; if so, this would explain why so few of its patterns, which admittedly constitute a catalog of ideal types, can be identified with designs on extant monuments. Only a handful of Timurid-Turkmen and early Safavid buildings survive in such Iranian cultural centers as Tabriz, Qazvin, Isfahan, Yazd, and Shiraz. Although the parallels that we have identified for the Topkapı scroll involve extant monuments located in Iran, primarily along the axis between Isfahan and Yazd, the capital Tabriz was the major cultural center from which architectural and decorative innovations were disseminated to these neighboring regions.[80]

Judging from its cityscape as drawn by the Ottoman artist Matrakçı Nasuh in the 1530s, Tabriz once rivaled the Timurid capitals of Samarqand and Herat in architectural splendor. The nearly wholesale destruction of monuments in Tabriz is, therefore, as significant a loss for the history of eastern Islamic architecture in the post-Mongol period as is the disappearance of Abbasid Baghdad for the pre-Mongol era.[81] In his historical essay on Tabriz, the late sixteenth-century Ottoman historian Taᶜlikizade still ranked that city—together with Istanbul, Cairo, Delhi, Beijing, and Rome—among the leading metropolises of the world. By implication this gave it greater prestige than Samarqand and Herat.[82] If the Topkapı scroll was compiled in the Turkmen or early Safavid courts of Tabriz (or in another Iranian city), its patterns can be seen as precious mementos of a now-lost archaeological record.

Confronted with the ruins of ancient Near Eastern monuments, the ninth-century Abbasid author al-Jahiz wrote: "The composing of books is more effective than building in recording the accomplishments of the passing ages and centuries. For there is no doubt that construction eventually perishes, and its traces disappear, while books handed from one generation to another, and from nation to nation, remain forever renewed."[83] Centuries later the Timurid historian Mirkhwand (1433–1498) would repeat the same observation: "Buildings may be seen, / Ruined by sun and rain. / Erect history's strong foundation / To escape from wind, rain, and desolation."[84] The survival of the Topkapı scroll in the face of the large-scale destruction of Timurid-Turkmen monuments in such centers as Tabriz bears out this sad truth concerning the evanescence of brick-based architecture in the Iranian world.

The question remains how the Topkapı scroll, meant to preserve the memory of geometric design traditions from one generation of master builders to the next in a manuscript-dominated premodern world uninfiltrated by the printing press, found its way into the Ottoman imperial treasury collection. Unlike the printed architectural manuals that proliferated in fifteenth- and sixteenth-century Europe, where the late medieval guild system had begun to disintegrate, the Topkapı scroll addressed a narrow circle of initiates already acquainted with inherited craft traditions. Since its coded working drawings recording workshop practices by means of economically rendered repeat units do not seem to have been intended as presentation drawings for patrons, its preservation in the sultan's private treasury seems unusual.

The circumstantial evidence of the Topkapı scroll's placement in the Inner Treasury of the Topkapı Palace can provide an additional clue as to its date and provenance. If it was produced in Tabriz or brought there from another Iranian center, it could easily have passed into the hands of the Ottomans who conquered Tabriz several times: the first in 1474 when Mehmed II defeated Uzun Hasan and the second in 1514 when Selim I vanquished the Safavid ruler Shah Ismaᶜil. On both occasions many skilled artisans and scholars as well as treasures and manuscripts were taken from Tabriz to Istanbul. This pattern was repeated in Süleyman I's several raids on the same city in the first half of the sixteenth century, which eventually forced the Safavids to transfer their capital to Qazvin in 1543. The scroll could also have been brought to Istanbul by such personages as the

Timurid astronomer-mathematician Ali Kuşcı, who first moved from Samarqand to the court of Uzun Hasan in Tabriz after the death of his patron Ulugh Beg and then joined Mehmed II's court in 1472 with a large retinue and a vast manuscript collection, which included mathematical treatises.

The Topkapı scroll may also have belonged to the Timurid-Turkmen decorators and builders who were invited to the court of Mehmed II in the 1470s. Completed in 1472, this sultan's Çinili Köşk (Tiled kiosk) at the Topkapı Palace was decorated by a foreign workshop staffed with tile cutters from the Iranian world. It exemplified the prestige of the international Timurid-Turkmen style in the Ottoman court at a time when Mehmed II was dreaming of appropriating the Aqqoyunlu territories in the east. It is tempting to propose that the scroll reached the Ottoman court some time in the late fifteenth or early sixteenth century when cultural contacts with the Timurid, Turkmen, and early Safavid courts were at their peak; this seems all the more likely given the diminished interest in Persianate artistic models after that time. The Topkapı scroll probably owes its superbly preserved condition to having been deposited in the Inner Treasury and then forgotten, thanks to its minor relevance to classical Ottoman architecture, the canonical language of which was codified by the 1550s and marked a deliberate departure from the Persianate Timurid-Turkmen models that previously had been emulated.[85]

If the Topkapı scroll had been used in the office of the chief architect, it would probably have disappeared together with all the architectural drawings cited in the Ottoman sources. This seems to have been the fate of many other pattern scrolls consumed during the construction process in the Iranian world. The combined evidence, then, strongly suggests a late fifteenth- or sixteenth-century date and an Iranian provenance for the Topkapı scroll, hereafter referred to as a Timurid-Turkmen scroll even though it may have been compiled in the Safavid period. Determining an exact date of compilation becomes a relatively minor issue since the predominantly geometric design repertory of the scroll is genuinely Timurid-Turkmen in origin, a repertory that continued to be used in the early Safavid era. In whatever context it was created, the implications of the Topkapı scroll for architectural practice in the late Timurid-Turkmen and early Safavid worlds are of far greater importance, implications that would not change even if this unique document were found to have been copied at a later date.

CHAPTER 3. THE TOPKAPI SCROLL AS A MIRROR OF LATE TIMURID-TURKMEN ARCHITECTUAL PRACTICE

The geometry that governed the two- and three-dimensional decorative revetments of Timurid-Turkmen architecture (perpetuated in early Safavid and Uzbek architectural practice) is the main subject of the Topkapı scroll. As Golombek and Wilber have remarked: "What supplies the unifying force to Timurid architecture . . . is the geometrization of design, structure, ornament, and space. Geometry in Timurid architecture is not merely a means to an end, but an end in itself—an underlying theme, an aesthetic principle. A building must not only have a geometric skeleton, but in the final analysis it must look 'geometric.' Geometry is as much a theme of the architecture as it is of the decoration." This obsession with geometry, they argued, turned it into "a form of design theory" in Iran and Central Asia during the Timurid period.[86] The Topkapı scroll, which once acted as an intervening medium in the conceptualization and transmission of architectural knowledge, can help us penetrate the processes of geometric harmonization in Timurid-Turkmen architecture where geometry constituted an important key to structural logic, beauty, and meaning.[87]

"The virtuosity of Timurid architecture," as Golombek and Wilber noted, "was not expressed primarily in the design of new types of structures, or in the elaboration of previous types, but in an intensive experimentation with decoration and with varieties of vaulting."[88] Robert Hillenbrand affirmed that "while architectural layouts remained traditional, the Timurids developed vaulting and tilework to a hitherto unprecedented degree."[89] It is precisely to this aspect of Timurid-Turkmen architecture that the Topkapı scroll with its intricate geometric patterns for polychrome surface revetments and elaborate vaulting is devoted. Buildings commissioned by the ruling elite stood out by virtue of their expensive decorative veneer of polychromatic revetments applied over a greater surface area than ever before in Iranian Islamic architecture. As stellate arch-nets and muqarnas vaults turned into a form of ornamental revetment complementing the decorative treatment of wall surfaces, their increasingly intricate designs freed from structural concerns had to be worked out in precise preliminary drawings.[90]

The cruciform dome chambers, weblike arch-nets, complex muqarnas vaults, extensive inscriptions, and geometric ornament of Timurid-Turkmen buildings almost certainly required detailed advance planning just as contemporary late Gothic architecture did. Although only a few architectural drawings are known from the Romanesque and early Gothic periods in Europe, a large number of workshop manuals, lodge books, and drawings from between the fourteenth and sixteenth centuries have survived, most of them pertaining to German late Gothic.[91] This parallels the proliferation of architectural drawings in the Islamic lands after the fourteenth century, which culminated in the earliest known examples of pattern scrolls datable to the late fifteenth and sixteenth centuries. Although this may simply be an accident of survival, the boom of drawings could also be the result of the codification of forms after an initial period of structural experimentation. Both the late Gothic and the late Timurid-Turkmen architectural idioms evolved from structural innovations that were eventually transformed into elaborate decorative sophistications. Like late Gothic flamboyant vaulting, which

has been described as being generated from a "disciplined geometric grid which explodes into fireworks of incredible technical and design sophistry," Timurid-Turkmen vaulting became an independent aesthetic force requiring more and more complicated designs.[92]

Surviving late Gothic design booklets and the Topkapı scroll reflect a shared preoccupation with the graphic representation of increasingly elaborate vault patterns and details of geometric ornament rather than with problems of architectural space and structure. As the plans of building types became relatively standardized with the dissipation of daring structural experimentation, late medieval architects in Europe and in the Islamic lands increasingly turned their creative energies to the decorative embellishment and refinement of canonical forms. As Spiro Kostof noted, late Gothic architects embarked on a "dazzling adventure of elaborations," designing lacelike tracery, infinitely variegated filigree work, fanciful vault schemata, and decorative motifs, which constitute the subject matter of their drawings. He perceptively compared the dematerialized muqarnas vaults of the Alhambra, with their myriad minutely fragmented facets, to late Gothic vaults in England: "The later vaults in both the Muslim and Gothic comparison may seem at first glance wildly licentious, but they are, each one within its own tradition, rationally bred from the visual principles that governed the earlier vaults."[93]

Like their late Gothic contemporaries, master builders in the eastern Islamic lands strove for refined virtuosity and subtly variegated surface revetments in multiple media, as the drawings of the Topkapı scroll with its kaleidoscopic array of geometric patterns, inscriptions, and vault projections show. Based on more visually complicated multilayered geometric compositions than their Gothic counterparts, the scroll's drawings provide a glimpse of the Timurid-Turkmen design repertory, governed by the abstract logic of geometry. These drawings demonstrate that the late Timurid-Turkmen architect, like his colleagues in Europe, had to master a modular system of geometric design in which arithmetic and measurement played a relatively insignificant role. Kostof stressed the predominantly geometric basis of the medieval design process, noting the shared preoccupation of both Christian and Muslim architects with geometry:[94]

> In mature Gothic design, arithmetical tidiness in the much more sophisticated geometry used was not always of prime concern. The design process evolved from a geometric progression that started with basic figures, such as equilateral triangles, circles, and squares, ending up, through a series of simple geometric steps, in elaborate constellations of form. In this dynamic manipulation of geometry the module had, as it were to fend for itself. Measured drawings were exceptional. Proportions were not fixed according to a respected general canon, as with Classical architecture. . . . In Gothic architecture, proportions are more abstract; the individual elements have no accepted set of proportions in themselves or in relation to the overall dimensions of the building, but rather follow a system of interrelationships grounded in the consistency of geometric formulae.[95]

Unlike Euclidean theoretical geometry, the practical constructive geometry of the medieval master masons did not require arithmetic reasoning to move through geometric processes.[96] Problems that would seem to require numerical computation were often solved through the construction and manipulation of simple geometric shapes, using basic working tools. As Lon Shelby observed, rather than being "the geometry of the mathematicians," this was the medieval mason's "way of visualizing potential architectural forms within certain geometric figures."[97] It was through a minimum inventory of geometric shapes that medieval architects created a maximum diversity of forms. Actual measurements did not enter the design process until the last moment, when the siting and dimensions of a building were determined, an observation confirmed by the absence of measurements on surviving working drawings. Among the approximately five thousand preserved Gothic architectural drawings, less than a dozen contain indications of actual size, some of them apparently added as an afterthought. Most of these designs were developed geometrically and thus were work-

able for large and small structures alike.[98]

The geometric drafting methods of medieval master builders differed fundamentally from those developed in post-Renaissance Europe. As Shelby noted, "Medieval architects—the master masons and master carpenters—did not work and think and write like ancient and post-medieval architects."[99] Their distinctive modes of conceptualizing design problems are reflected in Gothic sketchbooks and lodge books, which constitute valuable repositories of forgotten techniques and lost mental processes. Shelby's analysis of medieval architectural drawings led him to conclude that the "art of geometry" of the master masons produced significantly different ways of conceptualizing and visualizing the design process. In this process the template designed by the master mason and used by the masons to carve geometrically intricate stones for vaults, windows, portals, tracery, and other ornamental details played a key role: "Learning how to project three-dimensional forms from two-dimensional templates was one of the most important lessons a stonemason had to master. It was also a lesson which carried over into the most advanced task of the master mason, that of architectural design."[100]

The Topkapı scroll shows that a similar process of projecting spatial forms from two-dimensional templates was at work in Timurid-Turkmen architectural practice. The direct translatability of drawings on a flat plane into spatial forms reduced the need for precise elevation drawings, which are conspicuously absent in both the Topkapı and Tashkent scrolls. Elevations were often deduced by means of geometric procedures from ground plans, as was common practice in the Gothic building tradition.[101] Through methods of parallel projection multiple levels of space frequently were collapsed onto a single drawing just as two-dimensional designs were projected onto walls and vaults by means of imagined parallel rays. Workshop training prepared Timurid-Turkmen builders to read such multileveled drawings, which contained several superimposed horizontal cross sections. This technique enabled them to visualize three-dimensional constructs beneath crisscross geometric lines on paper. With scroll drawings acting as templates that provided easy shortcuts, builders and their specialized teams of decorators could apply even the most intricate geometric revetments on walls and assemble the most complex muqarnas or stellate arch-net vaults by simple means, guided by the practical experience they already possessed.

The Topkapı scroll indicates that Timurid-Turkmen architectural practice was closer in spirit to the Gothic than it was to the Renaissance tradition. Such Timurid master builders as Qawam al-Din Shirazi, who was active in the early fifteenth century, were essentially refining a traditional system of geometric harmonization much like their late Gothic colleagues. By contrast, contemporary Italian architects such as Filippo Brunelleschi (1377–1446) had begun to turn away from the medieval architectural heritage upon rediscovering the Vitruvian system of harmonic proportions based on arithmetic ratios echoing musical consonances.[102] It was only after the Renaissance that scaled architectural drawings (characterized by measured ground plans and elevations drawn according to specific dimensions) became the norm in European architectural practice, a development that broadened the gap between drafting conventions in Europe and in eastern Islamic lands where abstract geometric schemata prevailed. Number-based design has long been regarded as one of the key points in distinguishing Renaissance architecture from the Gothic tradition where metrical elements had played only a secondary role. The medieval geometric system of proportioning based on incommensurable ratios differed significantly from the arithmetic system of commensurable ratios favored during the Renaissance. Rudolf Wittkower linked the latter with the emergence of perspective: "Indeed, the concept of commensurability lies behind the emergence of the metrical, rational space of Renaissance perspective."[103]

As François Bucher observed, the "Gothic design concept thrived on the arithmetic irrationality of geometrically staggered proportions which are instinctively pleasant to the eye, but at the same time a puzzle to the measuring mind."[104] The dynamic Gothic method of design, based on geometric configurations involving little arithmetic, finds a striking parallel in the *girihs* of the Topkapı scroll, generated by the ingenious manipulation of abstract geometric grid systems unencumbered by arithmetic. Like their late Gothic counterparts these drawings are unaccompanied

by numerical notations corresponding to absolute measurements. Meant to be proportionally adapted to buildings and local materials at the construction site, they are ideal patterns contained in square and rectangular frames whose length-to-width proportion matters more than their actual dimensions.

The Topkapı and Tashkent scrolls have important implications for the study of late medieval architectural practice in the eastern Islamic world. The latter's juxtaposition of squared ground plans with designs for two- and three-dimensional architectural revetments testifies to the role of master builders in coordinating architectural design with surface decoration. Grid-based ground plans, in which each square of the grid represented a given number of bricks, made the accurate estimates of construction costs easier, guided the geometric proportioning of architectural layouts, and served as a convenient device for enlarging drawings full scale on the site.[105] Chardin's observations about the construction industry in seventeenth-century Safavid Iran indicate that architects were paid a percentage on each building based on the cubit measure of the height and thickness of walls. This practice explains the rationale for grid-based plans that consistently indicate wall thicknesses to facilitate such calculations:

> The Persians determine the price for masons on the basis of the height and thickness of walls, which they measure by the cubit, like cloth. The king imposes no tax on the sale of buildings, but the Master Architect, whom they call *Mamarbachi* [Turkish, *miʿmārbaşı*, "chief architect"], that is, Chief of Masons, takes two percent of inheritance allotments and sales. This officer also has a right to five percent on all edifices commissioned by the king. These are appraised when they are completed and the Master Architect, who has directed the construction, receives as his right and salary as much as five percent of the construction cost of each edifice.[106]

Ready-made tables for numerical computation, such as those provided in al-Kashi's fifteenth-century treatise, *Miftāḥ al-ḥisāb* (Key to arithmetic), simplified the process of calculation for the overseers of construction, who often prepared cost estimates for projected buildings and assessed their value upon completion.[107]

Analyses of Islamic buildings in Central Asia suggest that their structure frequently was informed by regulating geometric grids and that the square modules of ground plans drawn on paper were related to regionally varied cubit measures. The wide range of variation in regional Timurid-Turkmen cubit measures shows that dimensions were not a primary consideration in the predominantly modular system of architectural design.[108] The geometric process of proportioning the ground plans of buildings and their vaults, then, remained largely independent of their actual construction. Like the *girih*s for two- and three-dimensional decorative revetments that accompany them, surviving grid-based ground plans represent ideal building types that were geometrically proportioned prior to being converted into a chosen modular unit of measurement, either equivalent to or commensurate with the local cubit. This unit of measure would generate all the important dimensions of the monument under construction, just as a set module used in conjunction with geometric schemes was typical of Gothic architectural practice. The process of translating the grid-based plans into elevations must have required approximate adjustments on the building site of geometrically generated ideal forms corresponding to irrational numbers. That is why attempts to reconstruct the proportional systems of surviving medieval Islamic monuments are bound to remain largely unsuccessful.

It is not unlikely that elevation drawings of certain architectural details were prepared to complement the squared ground plans, even though they are missing from the Topkapı and Tashkent scrolls. Al-Kashi's treatise on arithmetic does provide geometric drawings for arch and dome profiles and for a muqarnas module, which he said was based on a drawing method used by practicing Timurid masons (see "The Muqarnas," ill. 2, in the present volume).[109] Elevations of arch and dome profiles such as the ones included in the Qajar architect Mirza Akbar's scrolls (see figs. 27, 28, 36)

may simply have been omitted from earlier scrolls because they would have been designed on the construction site according to geometric "rules of thumb," on the basis of required measurements.

The Topkapı scroll's few elevation drawings (see cat. nos. 35, 39, 105) point to a drafting tradition that relied heavily on ground plans from which elevations could be geometrically deduced during the construction process.[110] Profiles of windows, arches, and portals were most likely determined according to standard geometric procedures in the form of full-scale templates that were commonly used in Gothic architectural practice as well. The preparation of such drawings in plaster on the floor of the construction workroom in nineteenth-century Qajar Iran is described by Clarke:

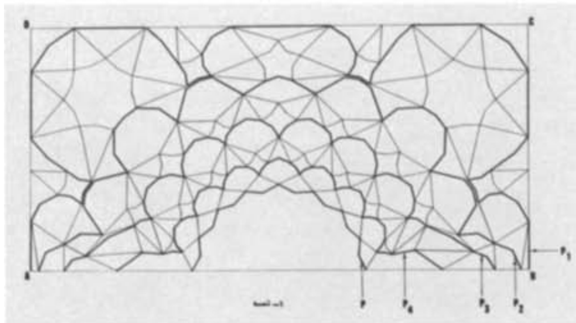
> Having described the use of the tracing board in Persia I shall now proceed to the floor of the workroom, which is generally a space within the building in progress, and here the full-size details are worked out either by enlargement by squares or geometrical methods mostly empirical. The preparation of this floor requires their greatest care, as its finished face is fine plaster of Paris evenly laid. The patterns, once worked out, are incised on the plaster, which being greased is ready to serve as a mould for slabs of plaster which are cast from it. These, which take the place of tracings of full size details with us, are given out to the workmen and serve as templates to shape the work to. Perfect accuracy and fitting of the several parts are thus assured, as all emanate from one original.[111]

Clarke also described how plaster muqarnas vaults were created by means of a method of parallel projection from a plan drawn full scale on the floor:

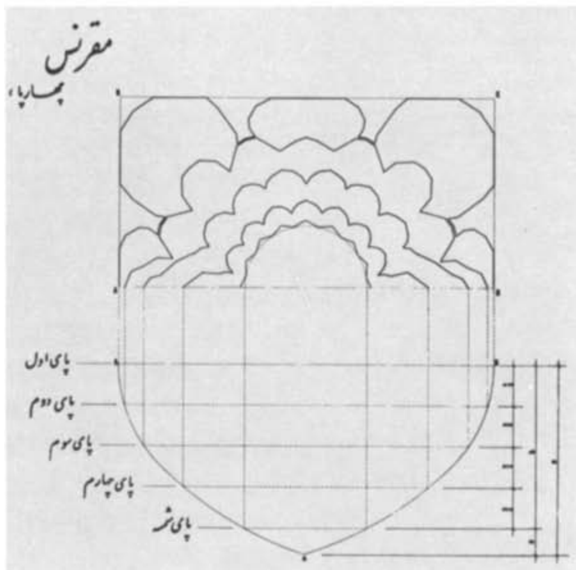
> The floor of the room to be vaulted was levelled on a bed of ashes, a thin coat of plaster was run over this, and the whole plan laid out; the lines were then cut out with a knife in a V form, and the plaster was saturated with hot suet. A cast of this was taken in plaster about half an inch thick, and the first plan, that is to say, the first line of stalactites were cut out by the workmen, stuck up horizontally against the wall, and supported by means of sticks and soft plaster; the visible part of the stalactite was then finished by hand down to the wall. Another sheet was then run and the second line was cut out, stuck on as before, and thus contained until the whole was completed. As the faces of the Persian stalactites all form plain rectilinear figures, it is not difficult to work them by hand.[112]

In 1881 a friend of Clarke's, who had seen the vault projections included in the Mirza Akbar scrolls (see figs. 27–30), commented, "Such is the habit which these Persian workmen have acquired, by long tradition and habit, of carrying out this work, that they are able to work out the most intricate patterns merely from such plans as you see roughly drawn."[113] George Aitchison also described how Persian builders constructed muqarnas vaults by translating the plans included in the Mirza Akbar scrolls into full-scale drawings on the floor, a procedure he compared with Gothic building practice:

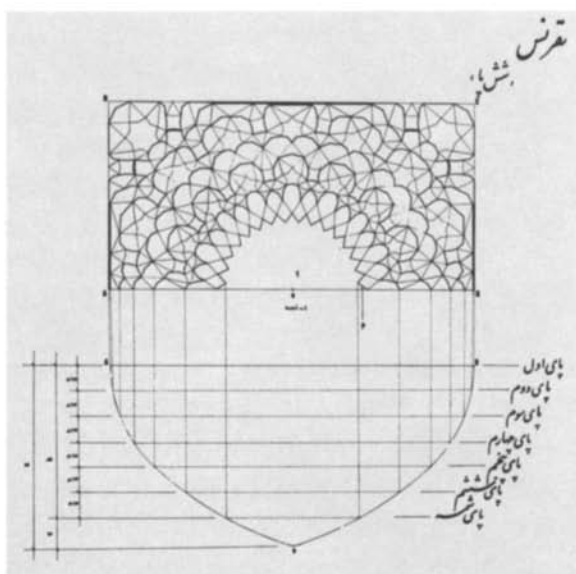
> Mr. Clarke was enabled to procure from the architects' guild a great number of their pattern-books, some of which are exhibited here, and it is most probable that something of the sort existed in the Middle Ages, when stellar and other complex vaulting was in vogue. These Persian pattern-books contain the plans only of all the most favorite Persian vaulting. When the size of the space to be vaulted is given, any master-mason can execute the stalactite work from the plan alone. This fact Mr. Clarke proved in the following way: he made a plan, elevation and section of a cornice at Teheran, and wishing to have a similar one at the British Embassy he was building, some hundred miles away, he showed the plan to the master-



67. Asgar Shiʿrbaf, ground plan of a muqarnas portal hood, Iran, twentieth century, ink on paper. From Shiʿrbaf, 1982–1983, 1: 91.



68. Asgar Shiʿrbaf, parallel projection of the muqarnas ground plan depicted in figure 67 to the vault of a portal, Iran, twentieth century, ink on paper. From Shiʿrbaf 1982–1983, 1: 94.



69. Asgar Shiʿrbaf, ground plan of a muqarnas portal hood and its parallel projection method, Iran, twentieth century, ink on paper. From Shiʿrbaf 1982–1983, 1: 97.

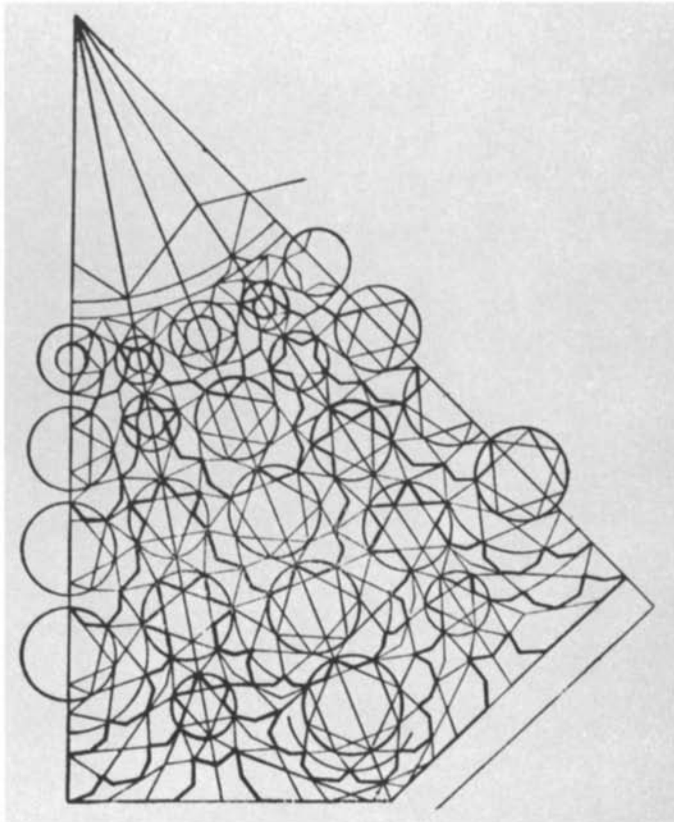
> mason and asked him if he could execute it from the plan alone. The answer was "Certainly," and when it was done Mr. Clarke verified it from his drawings, and found it exact.[114]

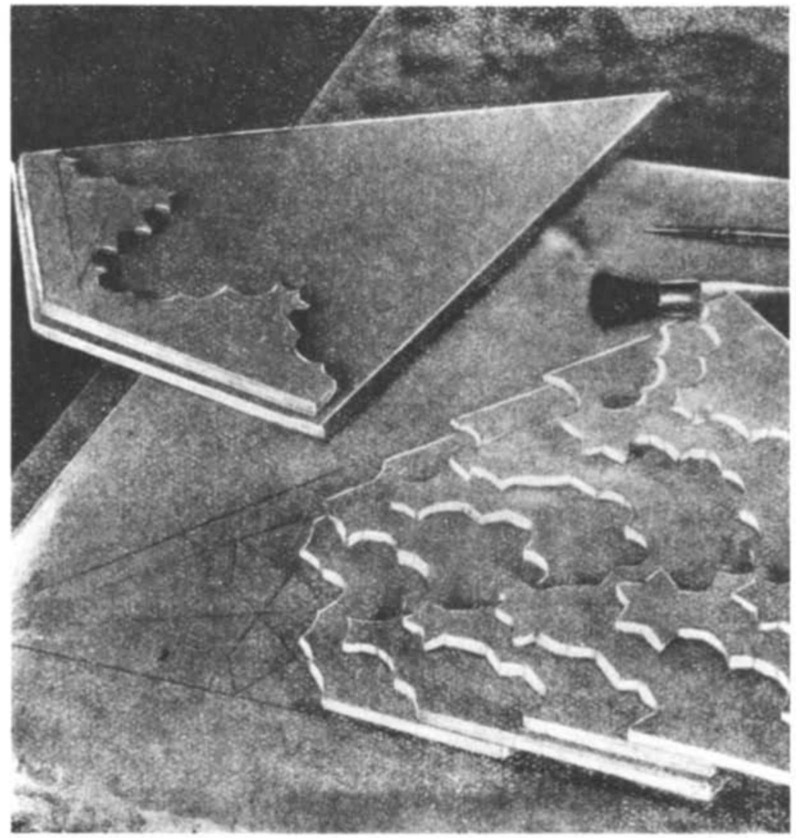
On the basis of a report from Clarke, the architect R. Phené Spiers described the Qajar method of vault construction in a "room with stalactite vaults at each angle and pendant in the centre":

> The plan was first made out on the floor, the outlines of the several levels being strongly marked out. Then thin slabs of stone were cut to the outline of each level and subsequently built in the wall at the required height. It should be noticed, therefore, that there would always be above the curved form of each course of stalactites an upright vertical surface from 1.5 inches to 2 inches deep; this is the template. When the bearing of the templates becomes too great, they are supported in the centre by chains from beams fixed above the stalactite ceiling, and in the case of pendant stalactites similar chains are suspended to take them. These chains are afterwards coated with plaster to make them rigid like columns. The positions of these templates and chains are carefully ascertained by plumbing from above down to the groundplan. The result will be a series of shelves or brackets, on which the plasterer commences his work, commencing at the bottom and moulding each stalactite niche resting on the lower template and working it up to the upper one.[115]

The nineteenth-century Qajar method of muqarnas construction was still in use in 1936 when Myron Smith saw the plasterers of Isfahan build a muqarnas semidome by scratching its full-scale design with simple instruments (straight edge, string, pair of dividers, and stylus) on the floor below, which had been covered with plaster of paris (*gach*). Their master first drew a rectangle corresponding to the vault's dimensions, sketching the outlines of the forward edges of the various horizontal strata, and continuing to design it in tiers, by visualizing its three-dimensional projection on the basis of his traditional empirical knowledge. After the design was finished, without the aid of a drawing on paper, black charcoal dust was brushed into its outlines. Beginning with the line corresponding to the top of the lowest tier, slabs of *gach* were cast on the floor and before setting hard they were turned over and trimmed with a knife to the black line left by the charcoal, an operation repeated tier by tier.[116] The same procedure is described in detail with step-by-step diagrams in recent publications by practicing Iranian master builders, testifying to the continued use of traditional vault-projection methods (figs. 67–69).[117]

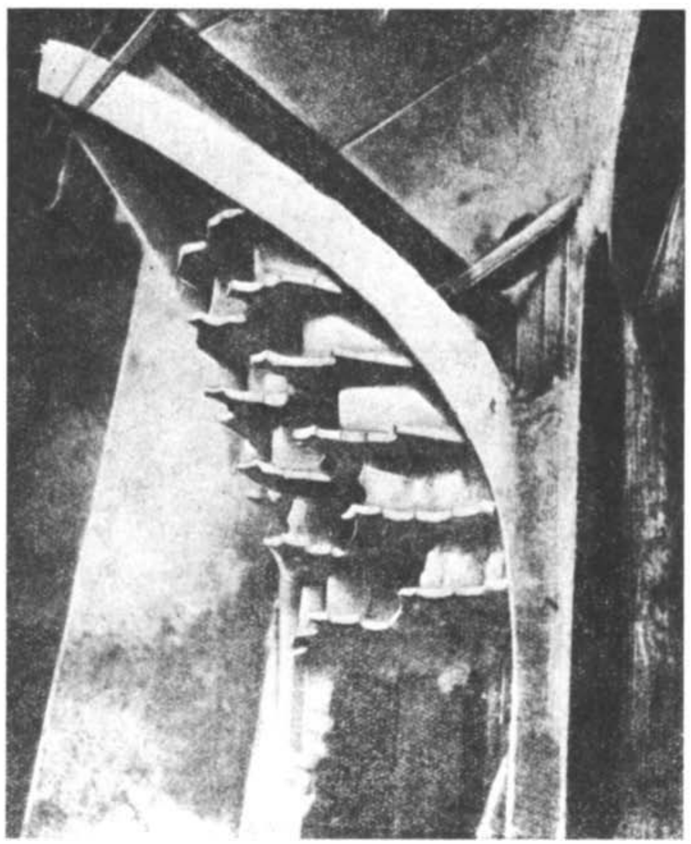
That the same technique was also widespread in Central Asia is demonstrated by Notkin's account of how the traditional Bukharan master builder

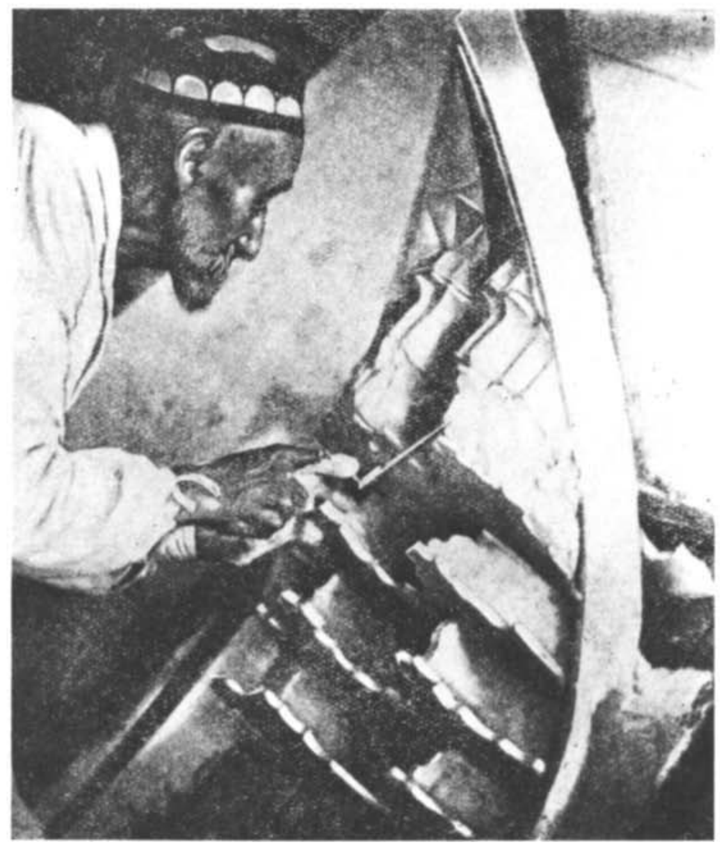




70. Usta Shirin Muradov, repeat unit of the ground plan of a muqarnas vault, Bukhara, twentieth century, ink on paper. From Notkin 1961, 88, fig. 46. Photo: Courtesy Iosif Isakevich Notkin.

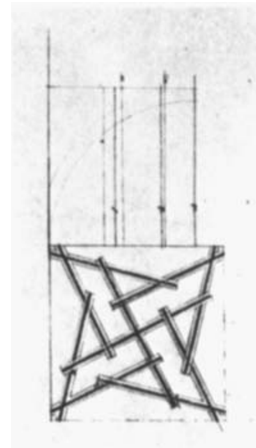
71. The preparation of plaster shelves on the ground from the full-scale muqarnas drawing (see fig. 70). From Notkin 1961, 88, fig. 47.. Photo: Courtesy Iosif Isakevich Notkin.



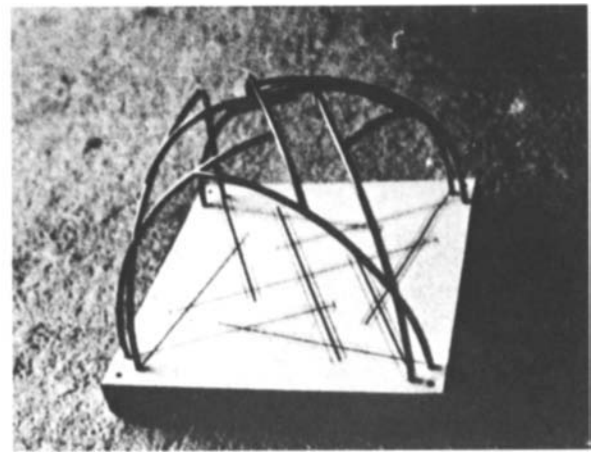


72. Shelves parallel to the ground set up on the vault (see figs. 70, 71). From Notkin 1961, 89, fig. 48. Photo: Courtesy Iosif Isakevich Notkin.

73. The final placement of individual muqarnas units in the shelves forming corbeled tiers (see figs. 70–72). From Notkin 1961, 89, fig. 49. Photo: Courtesy Iosif Isakevich Notkin.



74. Vault projection. From the Dresden Sketchbook, sixteenth century, ink on paper. Vienna, Österreichische Nationalbibliothek, MS Cod. Vind. min. 3, fol. 10v.



75. Vault model based on figure 74. Photo: Courtesy François Bucher and The International Center of Medieval Art, The Cloisters, Fort Tryon Park, New York.

Usta Shirin Muradov (1880–1957) both drew and constructed the fragment of a muqarnas vault (figs. 70–73).[118] Once again the plan on paper was traced full scale on the floor: from this tracing plaster plates 2 to 3 centimeters thick were cast for each row. They were attached to the vault with wooden supports and their correspondence to the plan was verified by plumb line. The attached plates formed successively corbeled horizontal shelves parallel to the floor, each shelf carrying rows of plaster muqarnas units serving a purely decorative function as a kind of sculptural surface ornament. This method of parallel projection required an ability to distinguish the boundaries of different tiers, which in the muqarnas drawings of the Topkapı and Tashkent scrolls are coded with graphic conventions that accentuate the edges of successive rows (see Catalog, Group IV.ii). Although an "anthropological" approach whereby historical building techniques are deduced from contemporary practices may be methodologically suspect, the modern eyewitness accounts cited above do help us visualize how the radial muqarnas patterns of the Topkapı and Tashkent scrolls, which were for the most part intended to be cast in plaster, would have been translated into spatial forms. This deduction is justified by the similarities between the relatively simplified muqarnas projections of the nineteenth-century Mirza Akbar scrolls and their more complex counterparts in the earlier Topkapı and Tashkent scrolls.

The patterns of stellate arch-net vaults must also have been drawn on the floor as full-scale templates from which builders could project the principal intersection points by plumbing from above (see Catalog, Group IV.i). It was common to trace ribbed or groined vault patterns on the floor in Gothic architectural practice as well; the method of projecting them into space constituted a craft secret jealously guarded by medieval masons.[119] According to Notkin the Tashkent scroll's vault projections, which are open to several alternative readings, exhibit a similar concern with protecting craft secrets.[120]

Like the Topkapı and Tashkent scrolls in which vault patterns constitute the largest group of drawings, many of the surviving late Gothic lodge books are dominated by vault patterns and their projection methods. A number of them are exclusively devoted to the problem of vault projection, which seems to have been a principal preoccupation of late Gothic builders.[121] These documents show that despite all its visual complexity, late Gothic vaulting was based on relatively simple geometric procedures. From the flat ground projection of the vault drawn full scale on the floor, one could deduce the length of the principal arch forming the apex of the vault as well as the respective lengths of interlaced ribs (figs. 74, 75). This method, which has been sufficiently tested in models to have proven foolproof and fundamentally simple, was based on the concept that all the ribs of a vault could be generated proportionally from its principal arc (*Principalbogen*).[122] Once the length of that arc was determined, the curvatures of remaining subsidiary arcs were generated from it by measuring the length of each as shown on the plan along a horizontal baseline; vertical lines were then struck upward from the endpoints of each of these rib plans. The length of the curved ribs was determined by the intersection of these vertical lines with the principal arc.[123] Similar vault projection plans with vertical lines are used by traditional master builders in contemporary Iran (see figs. 67–69).

Unlike their late Gothic counterparts, the muqarnas and stellate arch-net vault patterns in the Topkapı and Tashkent scrolls give plans without accompanying vertical projection lines providing their curvature. They often indicate only one-quarter of a vault pattern that could be adapted to produce a half or full vault, an economy of design that may have reflected a desire to conceal information from the uninitiated. Unlike their European equivalents the Topkapı and Tashkent scrolls were not meant to educate builders or to teach them vault projection methods but rather to guide those who were already well acquainted with the sophisticated graphic conventions used in representing three-dimensional constructs on paper. Unaccompanied by any annotations or written texts, these pattern scrolls functioned as an aide-mémoire for master builders familiar with traditional construction techniques.

That their coded system of graphic notation formed a collective basis for visual communication among master builders is suggested by a Persian nastaʿliq inscription on one of the muqarnas drawings in the Tashkent scroll that Notkin analyzed

(see fig. 13). The anonymous author of this inscription, which is scribbled in a narrow space between the projection of a muqarnas quarter vault and its triangular zone of transition, challenged his comrades or friends who are practitioners of this craft (*yārān-i ahl-i hunar*) to decipher the ingenious complexity of his design by counting its individual muqarnas tiers. Pointing out that "comrade" or "friend" is a common form of address in guild corporations infused with Sufi traditions, Notkin interpreted this to be the handwriting of a literate architect-engineer (*muhandis*) addressing his narrow circle of professional colleagues.[124]

The contents of the Topkapı and Tashkent scrolls support the commonly expressed view that the key to Timurid-Turkmen architecture lies not only in its fascination with complicated vaulting systems but also in its extensive surface decoration. The numerous two-dimensional geometric patterns and epigraphic compositions in these scrolls condense complex compositions into shorthand formulas meant to act as guidelines for the simpler working methods employed on the construction site. They thus provide a valuable glimpse into the processes of design and execution.

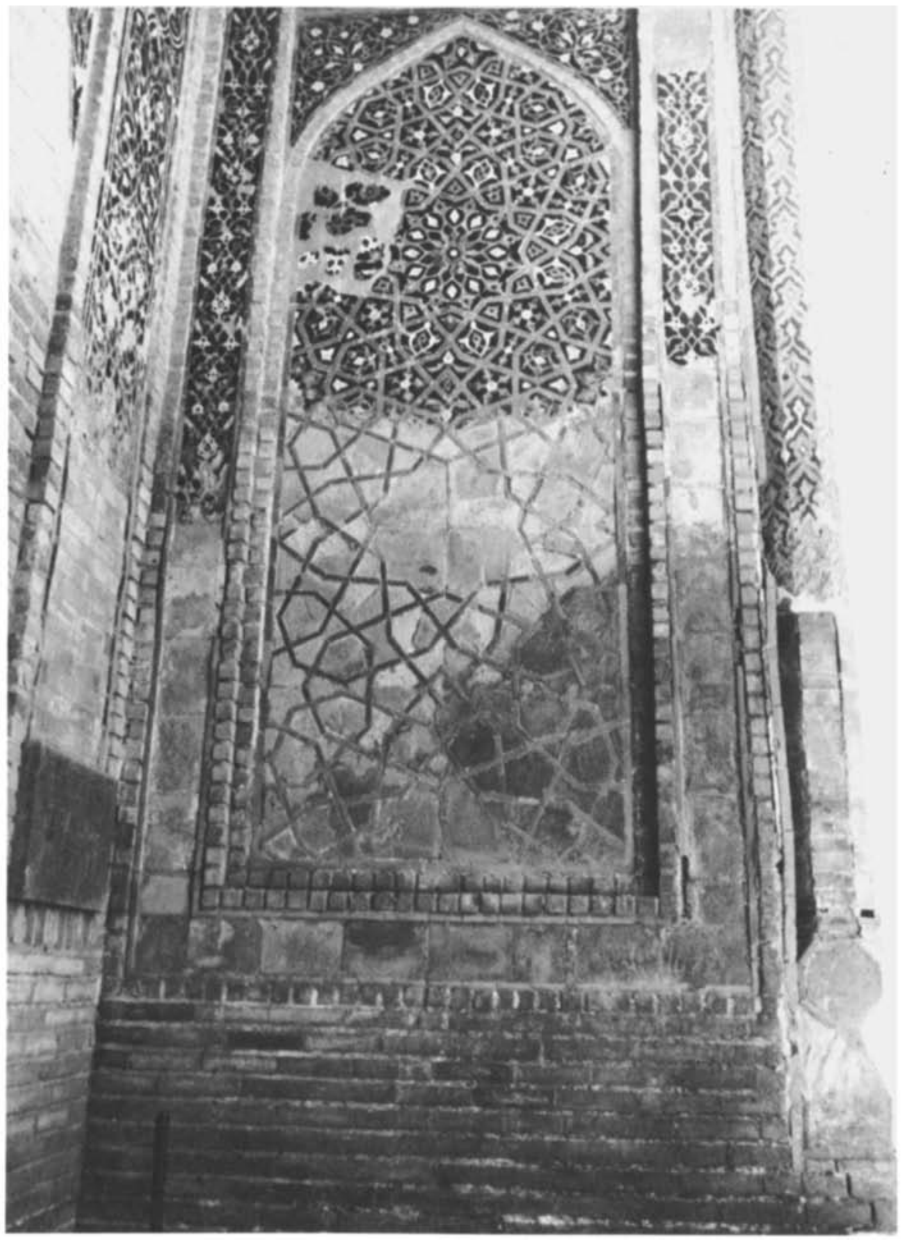
The advantage of squared paper in designing square kufic or naskhi inscriptions and geometric patterns for *bannā'ī* brick masonry is obvious. Designs on squared grids, though not drawn on a one-to-one scale, could easily be transferred to wall surfaces rendered in the *bannā'ī* technique, given the direct correspondence between the modular brick formats and the grid squares. Once the repeat unit of a design was executed on the wall as a model, even the most inexperienced artisans could multiply it by symmetry to cover extensive surfaces. The medium of plaster, with which most Timurid-Turkmen interiors are decorated, would have required the tracing of full-scale squared or polygonal grids on the wall. This is confirmed by the grid lines preserved on the plastered walls of an unfinished vestibule at the fourteenth-century Masjid-i Safid in Turbat-i Jam. Here, on one of the walls, prepared with a central panel featuring squared grid lines, a series of concentric circles have been scratched on the plaster with large compasses for a cursive inscription that was never completed.[125]

That the tracing of geometric grids on plastered wall surfaces must have been a relatively common practice is also suggested by the Mughal monuments of India, which were a regional offshoot of the Timurid architectural heritage. In 1905 Ernst Hanbury Hankin discovered several examples of interlaced geometric patterns that had been drawn with the aid of triangular and polygonal grids faintly scratched on the plastered walls of two baths in the late sixteeenth-century palace complex in Fatehpur Sikri. One was a design of interlocking rectangles generated by an isometric grid of equilateral triangles in the Hakim's Bath. The other was a geometric pattern of interlocking stars and polygons drawn on an underlying polygonal grid in the bath of Jodh Bai's palace. Hankin concluded that these grids formed by polygons in contact and probably applied to the walls with the aid of full-scale templates functioned as "the construction lines used in producing the pattern":

> It was obvious that polygons in contact were easy to draw. Having drawn them, pairs of lines had to be drawn passing through the centres of each of the sides of the polygons, at nearly the same angle in each case. Each line was prolonged until it met a similar line that had crossed the centre of another side of a polygon. When this had been done all over the surface that had to be decorated, nothing more remained to be done, for the pattern was completed.[126]

Most star-and-polygon patterns generated by radial grid systems can be condensed into shorthand formulas requiring the use of polygonal templates. In the Topkapı scroll polygonal grids or construction lines used in designing such two-dimensional star-and-polygon patterns are often highlighted with orange or red ink (see Catalog, Group III.i.b). These dotted or solid construction lines define grid networks with polygons in contact and are superimposed on complex patterns drawn in black ink. It would be easier to transfer such polygons onto wall surfaces than the multiple concentric circles used in generating the patterns on paper. Not all star-and-polygon patterns in the Topkapı scroll, however, are accompanied by construction lines defining polygons in contact. Those generated by more complex uninked radial grid

76. Geometric grid regulating curvilinear patterns at the mosaic tile-work side panel of the entrance portal, Gur-i Mir complex, Samarqand, ca. 1400–1404. Photo by author.



systems based on dynamic axes of symmetry use grids composed of stars and polygons in contact, which demonstrates that Hankin's formula was not universally applicable (see Catalog, Group III.i.a).

The Topkapı scroll implies that the role of Timurid-Turkmen master builders lay primarily in preparing carefully worked out designs on paper for variegated surface revetments, vault patterns, and geometrically proportioned ground plans, which in turn required coordinating the activities of specialized artisans according to a preconceived building program.[127] Geometric *girih*s drawn by architects were frequently complemented by patterns prepared in court scriptoria (*kitābkhāna* or *kutubkhāna*) for the decorative revetments of specific building projects. We know, for example, that the illuminators and calligraphers employed in the scriptorium of the Timurid prince Baysunghur in the 1420s produced designs for a wide variety of media, ranging from manuscript illumination, bookbinding, tent decoration, and tile work to cursive monumental inscriptions. Fifteenth-century albums of miniature painting preserved in Istanbul and Berlin, and most likely compiled in Turkmen Iran, contain examples of such patterns and calligraphy samples, some of which may well have been intended for architectural decoration.[128] Largely consisting of curvilinear floral, vegetal, and figural designs accompanied by cursive inscriptions intended for mosaic tiling and plasterwork, the patterns created in court scriptoria would have been translated by master builders and their specialized teams of decorators into available craft techniques. The geometric *girih*s of architectural scrolls provided disciplined grids that regulated and gave compositional unity to such curvilinear designs (fig. 76).

As Golombek and Wilber commented: "It may be stated that when a master builder, such as Qawam al-Din Shirazi, took a structure in hand he followed through on every stage of the work, from the working drawings to the design of the vaults and the working out of all types of decoration. One needs only to study the details of his structures to be convinced that this was the case, and that he had his own crew of decorators."[129] A double-page miniature in the *Ẓafarnāma* (Book of victories), circa 1467, which represents the construction of Timur's Masjid-i Jamiᶜ in Samarqand, confirms that construction and decoration were carried out by teams of specialized artisans working hand in hand under the direction of master builders and construction supervisors (fig. 77).[130]

The unprecedented increase of work signed by master craftsmen specializing in different media during the Timurid period has been interpreted as a measure of the rising status of calligraphers who designed monumental inscriptions and of tile cutters, plasterers, carpenters, and painters who decorated buildings.[131] This was an inevitable outcome of the specialized division of labor in a construction industry that increasingly relied on extensive surface revetments in multiple media. The Topkapı scroll reveals that preparing geometric drawings for two- and three-dimensional decorative revetments was an integral part of the architect's

77. Construction of the Masjid-i Jamiʿ of Timur in Samarqand, double-page miniature painting. From Sharaf al-Din ʿAli Yazdi, *Ẓafarnāma* (Book of victories), ca. 1467. Baltimore, The Johns Hopkins University, John Work Garrett Library, fols. 359v, 360r.

responsibility, in addition to dealing with problems of structural stability and architectonics.[132] The scroll's ingeniously varied *girih* patterns testify to a standardized, repeatable, and flexible approach to design through simple geometric means that produced sophisticated results. Permutations arrived at by manipulating by-then-standard schemes made possible a wide variety of intricate patterns, allowing the designer great scope for improvisation. The scroll's repeat units could be multiplied to cover large walls, but they could also be contained in frames, blind arches, niches, and narrow strips that subdivided the surfaces of Timurid-Turkmen buildings into richly orchestrated ornate compartments capable of engaging the viewer in a lively process of anticipation and surprise. The use of patterns and inscriptions differentiated by subtle variations of similar grids, by changes in scale (ranging from designs only legible at close range to others readable from a distance) or by a multiplicity of textures and colors, introduced optical nuances that energized building surfaces, adding spatial variety to familiar layouts. Like surface patterns composed of repeated geometric units, the buildings were themselves made up of a series of geometrically interrelated forms and spaces rhythmically echoing one another in architectural ensembles constituting a collection of sequentially ordered serial elements.

The Topkapı scroll does not, however, provide any clues as to how its individual patterns contained in discrete frames were related to one another and how they would be coordinated on the fabric of a building. That task depended on the unifying vision and relative expertise of architect-engineers who had mastered the methods of geometrically harmonizing two- and three-dimensional surface revetments with one another and with their architectural support. It was they who brought to life on buildings the *girihs*—sketched out in scrolls as abstract linear schemes independent of application to any particular medium—by determining the underlying geometric skeletons of decorative programs that artisans specializing in various techniques would then execute. Selected patterns were unified through a harmony of blues, shared geometric schemata, and dynamic proportions, but the polychromatic walls of Timurid-Turkmen monuments still read like a collection of separately framed motifs from scrolls, no matter how well integrated. These monuments carried the unmistakable imprint of an intermediary medium of drawings that left its distinctive mark on the final architectural product.

In the Timurid-Turkmen architectural tradition the degree of success in the process of geometric harmonization ultimately depended on the relative skill of available architects, since the use of proportioning devices, no matter how elaborate, does not necessarily guarantee harmonious results. Today, in retrospect, the conviction that applying complex geometric formulas could somehow assure the aesthetic coordination of structural and decorative schemes seems unfounded. The geometric layouts and surface patterns used by Timurid-Turkmen architects did not always lead to well-coordinated ensembles that fully integrated all aspects of plan, elevation, massing, and surface decoration. This is apparent in the relatively low rate of surviving monuments, their large percentage of collapsed domes, and their often unbalanced elevations characterized by harsh transitions between high domes, tall iwans, portal screens, minarets, and the much lower rectilinear walls that link them together.

Well-known instances of domes or portals being heightened in the middle of the construction process at the command of ambitious patrons such as Timur suggest that architect-engineers were not always responsible for the incongruity of proportions observed in some extant monuments. Such demands are quite revealing in terms of Timurid aesthetic sensibilities and demonstrate the importance of ostentation, spectacular effects, unprecedented monumentality, and daring height. The deliberate theatricality of extant monuments is exemplified by their privileging of elaborately decorated, overbearing frontal views that dwarf lateral or rear walls, which were sometimes left largely or entirely undecorated. Approached from their sides or the back, these spectacular buildings reveal the unintegrated proportions of their soaring portals, iwan screens, and domes awkwardly raised on tall drums, an indication that they were intentionally designed as stage sets meant to be viewed from particular vantage points.

The contents of the Topkapı scroll, which resemble those of a pattern book, can be seen as

an index of the unprecedented Timurid-Turkmen emphasis on surface decoration, an emphasis that turned the flat facades of buildings into stage props for the display of virtuoso ornamental panels and fragmented vaults into multifaceted compartments with no structural role. Theatricality, so central to the Timurid visual aesthetic in other artistic media, therefore, provides a key to architectural tastes as well.[133] Extravagant revetments added visual interest to standardized architectonic forms, enriching architectural experience through an optical complexity of detailing that raised the expressive potential of patterned surfaces and enhanced their ability to capture the viewer's attention. The resulting tension between the polychromatic veil of ornament and the structural skeleton of buildings was often skillfully turned into a dynamic dialogue in which the two complemented one another through shared geometric schemes.[134]

Variegated revetments added dynamic accents and textural richness to the dematerialized polychromatic walls and shallow screens of the two-dimensional world of Timurid-Turkmen architecture, so closely related in aesthetics to the arts of the book. Completely covering the inner and outer surfaces of buildings with variously framed colorful patterns and inscriptions not only brought these monuments close in spirit to the fantastic architectural settings represented in contemporary miniature paintings but also to album pages displaying an array of drawings and calligraphy samples. The Topkapı scroll, then, reflects a "painterly" aesthetic of architecture informed by the cultural prestige of drawings on paper. It embodies a conception of architecture as a sequential series of ornate walls and vaults, never perceived as wholes but only as partially revealed complicated surfaces experienced through movement in time and space. This conception of architecture as a dramatic interplay of structure, ornament, color, sculptural effects, textures, and light presupposed the subjective processes of visual perception, which, as we shall see in part 5, was consistently stressed in the primary sources. We shall turn to those sources after reviewing the secondary literature on Islamic geometric ornament.

NOTES TO PART 1

1. Clarke 1893, 100.
2. al-Yaᶜqūbī 1937, 11.
3. For al-Tabari's passage and other sources on the foundation of Baghdad, see al-Sayyad 1991, 117–23; and Lassner 1970. The common practice of tracing plans on the ground with plaster is discussed in Creswell 1932–1940, 1: 109–11. For a Mamluk amir who marked the plan of a building on the ground with whitewash, see Wilber 1976, 32. The practice of tracing plans on the ground in the Ottoman period is discussed in Necipoğlu 1986, 234.
4. Translated in Lassner 1970, 49–59, 79.
5. Cited in Swelim 1994, 182, from the tenth-century *Sīrat Aḥmad Ibn Ṭūlūn* (Life of Ahmad Ibn Tulun) by Abū Muḥammad ᶜAbd Allah b. Muḥammad al-Madīnī al-Balawī. For Bryas, see Eyice 1959; and Runciman 1980, 223.
6. For these two drawings (on large folios measuring 51 cm × 47 cm) discovered in the Great Mosque of Sanaᶜa in Yemen, see von Bothmer 1988, 178–81, and pl. 2. They are also discussed in Grabar 1992, 155–93, where an eighth-century Umayyad date is proposed.
7. al-Fārābī 1961, 52, 138–40; Ibn Miskawayh 1968, 104. For textual references to architects, see Bulatov 1988.
8. Translated and discussed in Grabar and Holod 1979–1980.
9. al-Ghazzālī 1970, 30–31.
10. William H. Morley's edition of Bayhaqi's history is cited in Wilber 1976, 31. Here the reference is to the plan of a new palace designed by Masᶜud I and executed by the architect-decorator ᶜAbd al-Malik al-Naqqash al-Muhandis.
11. Ibn Bībī 1959, 148.
12. Cited in Wilber 1976, 31. Among later Muslim rulers who are known to have drawn plans for their own building projects are the fifteenth-century Ottoman sultan Mehmed II (see Necipoğlu 1986) and the seventeenth-century Khan of Bitlis (see Evliyā Çelebi 1990, 96). As Evliya recorded (I have slightly modified Dankoff's translation of this passage), "In the science of architecture (*ᶜilm-i miᶜmārī*) he [the khan of Bitlis] is such a master geometer-engineer (*ṣāḥib-i hendese*) that the plan (*ṭarz [u] ṭarḥ [u] resm*) of the great palace described above is entirely his own conception." Another seventeenth-century ruler who drew plans is the Mughal emperor Shah Jahan; see Begley and Desai 1989, 10.
13. Cited in O'Kane 1987, 34.
14. Harb 1978.
15. Jaᶜfarī 1960, 88–89; cited in Blair 1986, 33.
16. Jaᶜfarī 1960, 89–90, 95.
17. The history of paper is summarized in Pedersen 1984, 54–71. For the role of paper as a medium for the transmission of architectural knowledge, see Holod 1988, 1–2. The argument that architectural drawings on paper must have been relatively rare in the pre-Mongol era, when verbal transmission and the imprecise copying of actual buildings played a more important role, is made in Bloom 1993.
18. Dawlatshāh al-Samarqandī 1901, 340. The same architect, referred to in an early sixteenth-century source as "Ustād Qawām al-Dīn miᶜmār-i Shirāzī," is praised as the "chief and refuge of the engineers/architects (*muhandisān/miᶜmārān*) of the age"; see Khwāndamīr 1954, 4: 14–15. For an English translation, see Thackston 1989, 159. During the Timurid period plans inscribed on plaster tablets continued to be used, complementing those drawn on paper. For a reference by the historian Yazdi to a plan (*ṭarḥ*) on a tablet (*lauḥ*), see O'Kane 1987, 34.
19. Ibn Khaldūn 1967, 2: 359.
20. For the dispatch of architectural drawings within the Ottoman empire, see Necipoğlu 1986, 241–43. A plan sent by the Mughal ruler Shah Jahan to his governor in Delhi is cited in Qaisar 1988, 14. A letter written in 1529 by the Mughal ruler Babur and sent to Kabul refers to the use of drawings in the construction of a mosque, caravanserai, baths, and other structures: "Let this work be ordered after taking counsel with Ustād Sulṭān Muḥammad; if a design exists, drawn earlier by Ustād Ḥasan ᶜAlī, let Ustād Sulṭān Muḥammad finish the building precisely according to it; if not, let him do so, after making a gracious and harmonious design"; see Nath 1982–1985, 1: 126.
21. See Chardin 1811, 2: 388–89: "The king Tahmasp had this fairly small palace built according to the plan that a Turkish architect gave him."
22. The plans of Baghdad and Isfahan are cited in Qaisar 1988, 15. The Lahori quotation is translated in Begley and Desai 1989, 10.
23. Kaempfer 1977, 113.
24. Du Mans 1890, 209.
25. Surviving Ottoman plans and textual references to architectural drawings in Ottoman sources are discussed in Necipoğlu 1986. The textual and pictorial evidence for Mughal plans (*ṭarḥ*) is discussed in Qaisar 1988, 14–15, 37–39.
26. For Uzbek plans, see Baklanov 1944. The Rajput plans are reproduced in Tillotson 1987, 104; and Begley and Desai 1989, 10, fig. 10. The Qajar plans are discussed in Clarke 1893.
27. For the Ayyubid scrolls, see Sourdel-Thomine 1986.
28. See Baklanov 1947, 102; and Gaganov 1958. The Tashkent scrolls, originally cataloged in boxes 16–23 at the State Public Library in Tashkent, have been recataloged as folders 1–8.
29. Baklanov 1944; idem 1947.
30. Gaganov 1958.
31. Rempel' 1961, 397–415; Pugachenkova 1962; Pugachenkova and Rempel' 1965, 323–24; Bulatov 1988, 265, 301; Notkin 1995. These Russian publications are discussed in Holod 1988. Because the transferred and recataloged Tashkent scrolls were lost track of, Holod was unable to locate them. Similarly, Golombek and Wilber wrote: "A full discussion of these rare drawings would be highly desirable. Their present whereabouts has not been ascertained"; see Golombek and Wilber 1988, 1: 173. I was able to find these drawings in 1989 at the Institute of Oriental Studies at the Academy of Sciences in Tashkent.
32. For geometric harmonization and modular planning in Central Asian Islamic architecture, see also Bulatov 1988; Kriukov 1964; and Zakhidov 1982.
33. Some designs in this folder (originally no. 16) are reproduced and analyzed in Baklanov 1947. Referred to as a "booklet of geometric ornament (*daftar-i gerikh*)," it is said to have been discovered by M. C. Andreev in 1936 in the collection of the Bukhara Museum; see Gaganov 1958.
34. This scroll fragment (originally no. 17) contains muqarnas projections (framed in 31.5 cm × 31.5 cm squares). It was first discussed in Baklanov 1944. For the same scroll fragment and reproductions of some of its ground plans and muqarnas drawings, see Pugachenkova 1962; and Pugachenkova and Rempel' 1965, figs. 298–99. Recently Notkin has studied the muqarnas and arch-net vault projections in the Tashkent scrolls; see Notkin 1995.
35. The contents of these six folders can be summarized as follows: no. 18: twelve folios of drawings in black ink of stellate arch-net vaults; no. 19: two folios (24.5 cm × 31 cm and 24.5 cm × 26 cm) with four projections of muqarnas quarter vaults in black ink highlighted in red and green; no. 20: eight partial muqarnas projections (contained in 22.3 cm × 22 cm frames) rendered only in black ink (with some units marked by small circles) and designs for two-dimensional geometric ornament; no. 21: drawings in black ink of partial muqarnas vault projections coded with small circles (contained in 11 cm × 11.5 cm or 23 cm × 23 cm frames) and of stellate arch-net vaults; no. 22: a cursive inscription fragment of Persian poetry in black ink, pricked with holes for pouncing, and a brown leather flap originally belonging to one of the scrolls; no. 23: eight projections for muqarnas quarter vaults in black ink using the same small circles (contained in 23 cm × 22.5 cm to 23 cm × 23 cm frames). The muqarnas projections in this group of drawings are studied by Notkin, who dated them all to the sixteenth century; see Notkin 1995.
36. The term *yazdī bandī* is mentioned in Smith 1947,

101, 110, 136–37. For drawings used in the construction of *yazdī bandī* vaults in contemporary Iran, see Shiʿrbaf 1982–1983; Firishtah Nazhad 1977; and Lur'zadeh 1979. Notkin refers to intersecting arch-net vaults as *iroki*, a term used by traditional Central Asian master builders at the turn of the twentieth century. Notkin disagrees with the theory that this term refers to the Iraqi origin of arch-net vaults but does not provide any alternative explanation; see Notkin 1995. The term may well refer to the broader region traditionally known as the "two Iraqs" (Arab and Persian).

37. For the concept of the "repeat unit," see El-Said and Parman 1976; and Critchlow 1976.

38. For the traditional Iranian practice of sketching full-scale designs on the floor with plaster, see Smith 1947, 132–34; Spiers 1905, 37–38, 52–54; and Clarke 1893, 99–101. For extant drawings scratched on various parts of Gothic cathedrals, see Schöller 1989.

39. Baklanov 1947, 102–111.

40. Ibid.

41. Rempel' 1961, 397–415.

42. Bulatov's discussion of various geometric grid systems is summarized in Golombek and Wilber 1988, 1: 159–73.

43. Notkin 1970; idem 1995.

44. This is convincingly argued in O'Kane 1987, 34.

45. For examples of later scrolls, see Baklanov 1947, 108; and Rempel' 1961, figs. 206–10, 220–24. The sketches of the traditional Bukharan master Usta Shirin Muradov (1880–1957) are studied in Notkin 1961. Notkin 1995 refers to relatively simple, freehand drawings by such contemporary masters as Khuli Dzhalilov of Samarqand and Usta Shirin Muradov that are preserved in the Museum of the Arts of Uzbekistan; see Notkin 1995.

46. Clarke 1893, 101.

47. The two surviving scrolls are numbered 54 and 55 and are now kept in the library of the Victoria & Albert Museum. The note states, "Le tracé à la pointe en blanc indique le base de la formation des figures."

48. These designs pasted on fifty-three cardboard sheets (80 cm × 56 cm) are numbered 1–53.

49. Christie 1929, 43, 267–70, 252–55. Christie analyzed selected designs from the Mirza Akbar scrolls; see idem, figs. 36, 244, 267, 269, 286, 287, 290, 291, 306. Gombrich, who acknowledged his debt to Christie's work, also published some patterns from the same scrolls in his book on ornament; see Gombrich 1979, 85–86, pl. 36. The Mirza Akbar scrolls, which I examined in 1987, were also noted by Wasma'a K. Chorbachi, who located the collection through Christie's publications; see Chorbachi 1989, 754–55. I first had referred to the Mirza Akbar scrolls in Necipoğlu 1986, before having seen them. For my preliminary observations on these scrolls, presented at a conference on Timurid-Turkmen culture held in Toronto in 1989, see Necipoğlu 1992b. The Mirza Akbar scrolls subsequently were mentioned in O'Kane 1992.

50. Clarke 1893, 100–101.

51. The term *ṭūmār* is used in the introduction of Khanlari n.d. I would like to thank Dr. Chahryar Adle for sending me a photocopy of the shorter French version of this text, which was published by the Fondation de la culture iranienne in the 1970s. For *ṭmars* still used in Iraq, see O'Kane 1987, 55 n. 40; he referred to an unpublished Ph.D. dissertation unavailable to me (A. Gailani, "The Origins of Islamic Art" [Ph.D. diss., University of Edinburgh, 1974], 142, 148).

52. Sotheby's London 1985, no. 311.

53. For the Shirazi scroll, see the introduction in Khanlari n.d.

54. For treatment of two- and three-dimensional *girih*s as related categories, see Shiʿrbaf 1982–1983; and Lur'zadeh 1979. The contemporary Iranian master builder Muhandis Zuhrah Buzurgmihri similarly referred to all types of geometric patterning (including those on vaults) in Iranian architecture as "*kār-bandī* = *rasmī bandī*"; see Buzurgmihri 1982.

55. For the muqarnas and its various interpretations, see Rosintal 1928; Hautecoeur 1931; Diez 1987; Herzfeld 1942; Jones and Michell 1972; Ecochard 1977; Ödekan 1977; Harb 1978; Tabbaa 1985; Behrens-Abouseif 1993; and Fernández-Puertas 1993.

56. Cited in O'Kane 1987, 55 n. 40. For the continuing use of nineteenth-century scrolls in some parts of the Arab world today, see also Chorbachi 1989, 756, fig. 2; 772, fig. 14. In 1981 Chorbachi examined these "paper scrolls of geometric patterns" from the master artisan's workshops of two unspecified Arab towns. These scrolls, illustrated in Chorbachi 1989, which are "still in the hands of artisans today . . . were not only the basic reference manual, but also served as a design book from which artisans chose the appropriate pattern to be used in architectural decoration or in the workshop"; see idem, 755.

57. Paccard 1980, 1: 134, 20.

58. For the establishment of schools in the traditional decorative crafts by the French, see Wright 1991, 131–33.

59. See López de Arenas 1966. López de Arenas's manual was reprinted in 1727, 1867, 1912, and 1982. The author, like his father, was a master carpenter and master builder (*alarife*). He wrote this technical "how-to" manual (filled with specialized terms) for his colleagues at a time when traditional geometric formulas had started to be forgotten. I would like to thank Dr. Lauro Elmo for translating the particularly difficult section on the muqarnas (*mocárabes*), chap. 18, fols. 23r–24r. For an analysis of the terminology and geometric structure of the type of Spanish muqarnas described by López de Arenas, see Fernández-Puertas 1993; he pointed out that the *mocárabes* (a term derived from *muqarbas*, which seems to be a corruption of muqarnas) were composed of four basic types of interlocking prisms, the rectangle and three kinds of isosceles triangles—40, 90, and 135 degrees.

60. See Paccard 1980, 1: 216: "The star-shaped polygon is the form that dominates all decoration. . . . It is obtained by dividing a circle into equal parts."

61. Paccard described el Bouri's muqarnas designs based on the square module thus: "These complicated structures are actually based on a square. In this case, by being turned diagonally, an eight-pointed star (*mthemmen*) or an octagon is produced"; see Paccard 1980, 1: 294.

62. Referring to Moroccan plaster muqarnas vaults, Paccard wrote: "The design of the plaster stalactite is quite different from that of the wooden stalactite, in that it is not based on the 90/45° grid. In fact, the negative of the pieces that are used as molds can be arranged among each other according to wider angles. This technique permits a tighter fit to the spherical curve and a greater freedom of execution"; see Paccard 1980, 1: 297.

63. For the specialized vocabulary of Moroccan geometric patterns, where the main generating circle of underlying radial grids is called "mother" (*oum*) and smaller subsidiary circles surrounding it are known as "sisters" (*oukht*), while the radii connecting them are called "pathways" (*zqaq*), see Paccard 1980, 1: 218–19. For the modern Iranian vocabulary relating to both individual geometric design components and their combination in codified *girih*s, see Firishtah Nazhad 1977. The names provided by Firishtah Nazhad reveal that the repeat units of *girih*s are often designated by the number of the points of the stars used in them. For example, patterns combining six- and five-pointed stars are referred to as "*girih* of six and five" (*girih-i shash wa panj*), or of twelve- and six-pointed stars as "*girih* of twelve and six," (*girih-i duwāzdah wa shash*). Occasionally more suggestive terms such as "twelve and six heavens" (*duwāzdah wa shash gardūn*) or "twelve and eight heavens" (*duwāzdeh wa hasht gardūn*) are used for stellate compositions replete with heavenly associations. For pattern names used by contemporary Iranian master builders, see also Lur'zadeh 1979. Names used for geometric patterns in Central Asia are mentioned in Notkin 1995.

64. Clarke 1893, 100–101.

65. This inventory is reproduced in Öz 1938, no. 21, fol. 14.

66. The Şehzade mosque's plans and drawings are mentioned in Celālzāde 1981, fol. 377b.

67. Drawings (*rüsūm*) of the Kaʿba that Sinan had made were kept in the archives of the Office of Royal Architects at Vefa; see Caʿfer Efendi 1987, 54, 56.

68. See Necipoğlu 1986, 224–43.
69. See Rogers 1989, 135; and my preliminary analysis of the Topkapı scroll in Necipoğlu 1992b.
70. For a discussion of Bulatov's views, see Golombek and Wilber 1988, 1: 138, 172.
71. Golombek and Wilber 1988, 1: 69, 164–69. For al-Kashi's discussion of the muqarnas, see also Dold-Samplonius forthcoming; and idem 1992a.
72. See illustrations in Golombek and Wilber 1988, 2: 334, 339, 352–54, 415, 417.
73. Çağman has pointed out the similarity of the Topkapı scroll's format and its paper size to a *ṭūmār* of calligraphy samples prepared for sultan Mehmed II that was signed in one place by a Tabrizi scribe in 1458. It is described in Çağman 1983, 111, no. 10. The rag paper used in the calligraphy scroll is 34 to 35 centimeters high; because a larger paper format was unavailable, the scroll's height was increased by pasting on additional narrow bands of paper. The type of paper used in the Topkapı scroll measures approximately 34 centimeters in height; the lengths vary (the longest pieces range from 48 cm to 52 cm). Since the leather flap pasted at the beginning of the Topkapı scroll is 31.5 centimeters high, the paper's height is adjusted to it at the beginning of the scroll. From 31.5 centimeters the scroll gradually expands to 33.5 and 34 centimeters.
74. See Golombek and Wilber 1988, 1: 412–14; 2: 430, 435.
75. According to Golombek it was restored in 1412–1419; see Golombek and Wilber 1988, 1: 412. The restoration is dated to 1441–1442 in O'Kane 1986, pls. xli–xlii.
76. See Golombek and Wilber 1988, 1: 372–75, 414–18; 2: 355–56, 439; and O'Kane 1986, pls. 37b, 38, 39b. The variants of this popular motif appear in the late Safavid Mader-i Shah Madrasa in Isfahan, which was built in the early eighteenth century, and in the Mirza Akbar scrolls at the Victoria & Albert Museum.
77. Examples appear in the Masjid-i Maydan-i Sang in Kashan (1460s), in a mosaic tile minbar at the Masjid of Amir Khizrshah in Yazd (illustrated in Golombek and Wilber 1988, 2: 462), and in the interior decorations of the Gur-i Mir at Samarqand.
78. See Golombek and Wilber 1988, 1: 384–87; 2: pl. xva.
79. For a list of monuments that feature similar relief tiles, see O'Kane 1987, 70. See also Golombek and Wilber 1988, 1: 328–31; 2: pl. xiia.
80. Most of the architectural novelties characterizing the imperial Timurid style of Khurasan and of Central Asia were introduced by architects whose *nisbas* connect them with such cities as Tabriz, Shiraz, and Isfahan. For these *nisbas*, see Golombek and Wilber 1988, 1: 188.
81. The topographic miniature of Tabriz is reproduced in Naṣūḥ 1976, fols. 27v–28r. The Timurid-Turkmen architecture of Tabriz is discussed in Golombek and Wilber 1988, 1: 30–31.
82. Taᶜlīḳīzāde Meḥmed Ṣubḥī Çelebi b. Muḥammed el-Fenārī, *Tebrīziye* (On Tabriz), MS R. 1299, fol. 38, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul. The historian Khwandamir wrote in the year 1523–1524 that Tabriz was the most flourishing city of the inhabited quarter of the world; see Khwāndamīr 1954, 4: 652–53.
83. Abū ᶜUthmān ᶜAmr b. Baḥr al-Jāḥiẓ, *Kitāb al-ḥayawān* (Book of animals), cited in Bosch, Carswell, and Petherbridge 1981, 5–6.
84. Mīrkhwānd 1891–1894, 1: 21. This topos is also encountered in the twelfth-century work *Chahār Maqāla* (Four discourses), which points out that books are more effective as memorials to the glory of past rulers than painted palaces and charming gardens; see Niẓāmī ᶜArūẓī 1978, 30–31.
85. For the Çinili Köşk and the impact of Timurid-Turkmen prototypes on Ottoman visual culture in the fifteenth and the early sixteenth centuries, see Necipoğlu 1991, 136–70; idem 1990b; and idem 1992a. The Topkapı scroll could also have been brought to Istanbul during the late sixteenth century when some parts of western Iran, including Tabriz, came under Ottoman rule, but the first half of that century is a more likely date for its acquisition, given the court's Persianate cultural orientation at that time.
86. Golombek and Wilber 1988, 1: 216, xxvi.
87. For the geometric harmonization of Timurid architecture in Central Asia, see Kriukov 1964; Zakhidov 1982; and Bulatov 1988.
88. Golombek and Wilber 1988, 1: xxii.
89. Hillenbrand 1989, 99.
90. O'Kane 1987, 74.
91. Except for the isolated thirteenth-century sketchbook of the French architect Villard de Honnecourt, the bulk of Gothic drawings fall into the period between the late fourteenth and the sixteenth centuries. See Shelby 1977; Bucher 1968; idem 1972; idem 1973; idem 1979; Koepf 1969; Rathe 1926; Müller 1973; idem 1975; and Recht 1989.
92. Bucher 1973, 44–48; Necipoğlu 1992b.
93. Kostof 1985, 387, 398.
94. Kostof 1986, 62.
95. Ibid., 85–86.
96. Shelby and Mark 1979, 117.
97. Shelby 1977, 78.
98. Bucher 1979, 1: 10; idem 1973, 48–49.
99. Shelby 1977, 6–7.
100. Ibid., 74.
101. Ibid., 74–77. See also Frankl 1945.
102. Wittkower 1988, 113. Golombek and Wilber's comparison between Qawam al-Din Shirazi and his contemporary Brunelleschi seems somewhat forced; see Golombek and Wilber 1988, 1: xxi.
103. Wittkower 1988, 150–54.
104. Bucher 1979, 1: 199.
105. According to Clarke, in Qajar Iran each square of the grid corresponded to either one or four bricks; the total number of bricks could be computed by counting the squares and multiplying the total by the height of the rooms (often proportionally related to their plan) after subtracting the openings for windows and doors; see Clarke 1893, 101.
106. Chardin 1711, 2: 80.
107. See al-Kāshī 1954; idem 1969; and idem 1977.
108. For the Timurid cubit (*gaz*), see O'Kane 1987, 34–35; and Kriukov 1964. Pugachenkova explained the function of the grid-based plans surviving in Tashkent as follows: "The plans are traced on a checkered surface permitting an observation of the exact proportion of parts in relation to the whole. The overall dimensions as well as the dimension of openings, supporting elements, and the thickness of walls are all indicated there. Each square of the grid represents a sort of architectural module called *giaz* [i.e., *gaz*] or *zer* [i.e., *zirā*ᶜ], which is one of the principal units of measure used by architects. The dimension of the *giaz* is not standardized in Central Asia, but since it constitutes a modular unit, what matters is that—independent of absolute dimensions—it indicates the proportions of diverse architectural elements drawn on the plan"; see Pugachenkova 1981, 21.
109. For a mathematical explanation of the mason's method for constructing the muqarnas, see also Dold-Samplonius forthcoming; and idem 1992a. Al-Kashi's method for measuring domes is analyzed in idem 1992b; and idem 1993.
110. Basing her comments on contemporary building practices in Central Asia, Pugachenkova observed that besides ground plans (*ṭarḥ*) indicating the outline of walls and openings, elevations were only occasionally prepared: "Most often, the elevation of the edifice is not anticipated in advance; the architect realizes his ideas directly on the construction site. Nevertheless, it also happens that—because of the dimensions of a projected edifice, its originality, or to satisfy the curiosity of a client—a sort of ground plan, the *tarz* [i.e., *ṭarz*], is prepared; this represents the edifice in elevation, together with the development of its central and two lateral facades." She added, however, that the ground plan sufficed in most cases: "Even for monumental edifices the plan constitutes the basis of work. Still today in Central Asia do they not construct complex arches and vaults or refined ensembles of stalactites, using similar plans traced on the ground, without a projection of volumes, simply with the indication of vertical sides? It was

thus that one already proceeded in the fourteenth and fifteenth centuries"; see Pugachenkova 1981, 21. We know that three-dimensional models were used in Ottoman building practice. Some nineteenth-century sources on the Taj Mahal refer to the preparation of a wooden model of the mausoleum after Shah Jahan selected one of the plans submitted on paper. Although models may have been used for outstanding Timurid projects, standard buildings would have required only ground plans. For Ottoman models, see Necipoğlu 1986, 236–42; the reference to the wooden model of the Taj Mahal is in Nath 1985, 7.

111. Clarke 1893, 101.

112. Clarke 1893, 175.

113. Clarke and Lewis 1880–1881, 168. Examples of Mirza Akbar's drawings for vault patterns are reproduced in this article.

114. Ibid., 173.

115. Spiers 1905, 37–38.

116. Smith 1947, 133–34.

117. Shiʿrbaf 1982–1983; Lur'zadeh 1979.

118. Notkin 1961. Paccard described the construction in Morocco of plaster muqarnas units cast in molds and ordered in tiers in similar terms: "The plaster worker begins at the bottom placing the molds in several rows, then he pours the plaster. When the plaster of Paris has set, he uses the molds again for higher rows, until the cap has been reached. The *muqarnas* are then carved, and often covered with painted decorations"; see Paccard 1980, 1: 296–97. Chardin observed that it was common practice in seventeenth-century Safavid Iran for carpenters to fully assemble joined woodwork vaults on the ground before lifting them into place by means of hoisting machines; see Chardin 1711, 2: 80.

119. Bucher 1973, 47; Frankl 1945. The proceedings of the meeting of lodges in Regensburg in 1459 read: "No workman, nor master, nor foreman (Parlier), nor apprentice shall teach anyone who is not of our profession and has not worked as a mason, how to derive the elevation from the plan"; see Bucher 1972, 527 n. 1.

120. Notkin 1995.

121. The contents of these lodge and sketchbooks are listed in Bucher 1979, 1: iii–v; Shelby and Mark 1979, 122–31; and Recht 1989, 282–83. The Frankfurt lodge book, 1560–1572, for example, has 222 projects, among them 147 vaults, 28 vault schemata, 23 windows, 6 geometric and decorative drawings, and other details such as sundials, stairs, and gables. Similarly the lodge book of Wolfgang Rixner (circa 1467–1500, with additions until 1599) contains 207 images of which there are 83 vaults, 27 traceries, 26 decorative and sculptural motifs, and 39 theoretical problems, as well as stairs, templates, and gables. The Dresden sketchbook from the second half of the sixteenth century, on the other hand, contains 32 vault designs of complex interpenetrating ribs with their projection procedures, and Jacob Feucht's treatise of 1593, intended as a handbook for Gothic architects, is mostly devoted to vault patterns and their projections. The Dresden and Feucht drawings (accompanied by vertical projection lines) provided the vault plan, the one and only curvature for all the ribs, and their actual lengths.

122. Bucher 1972, 527; idem 1973, 47; Shelby and Mark 1979, 125–26. The method is summarized by Shelby and Mark as follows: "First, the rib plan (*Reihung*) of the vault bay was drawn at full scale on the floor of the church, building lodge, or tracing house—wherever there was sufficient room for the task. Then it was determined what would be the highest point of the vault bay, and the distance was measured in the rib plan from one corner of the bay to that point. For example, in a quadripartite vault with semicircular diagonal ribs over a square bay, this distance would have been simply the straight line from one corner (the springer) to the center of the bay (the keystone) on the rib plan. But in the complex patterns of German *Spätgotik* the distance was determined by summing the lengths of the rib patterns from the springer to the highest keystone of the vault. . . . This distance was then transferred onto a horizontal base line and became the radius of a quadrant set out from that line. This quadrant was the *Principalbogen*."

123. Shelby and Mark 1979, 125–26.

124. The inscription cited in Notkin 1995 has been translated into English by Wheeler Thackston, Jr.: "Maʿlūm-i yārān-i ahl-i hunar bāshad dar shum[ā]rā-i īn muqarnas muqayyad bāyad shud tā az ḥāl-i īn kamā ḥaqquhu khabar yābī u napindārī īn ghalat karda ast" (May it be known to the friends who are practitioners of this craft [art] that in counting this muqarnas it is necessary to pay careful attention so that you may know about it as it ought to be and not think that this [fellow] has made a mistake).

125. O'Kane 1987, 36–37, pls. 0.1, 0.2.

126. Hankin 1905, 461–65.

127. Referring to the "universal" role of the Timurid master builder in supervising all aspects of architectural design and decoration, Pugachenkova wrote: "He has a knowledge of diverse architectural and decorative techniques. He is at the same time the author and executor of the project. He participates in all the phases of work; the initial conception emanates from his mind; his organizing talent assures the regular progression of construction activities; he executes with his own hands the most delicate pieces of work"; see Pugachenkova 1981, 27.

128. A document (*ʿarżadāsht*) dated 1420 lists the multimedia projects of artists employed in Baysunghur's scriptorium; for a recent translation of this source into English, see Thackston 1989, 323–27. The continuation of this tradition in the Ottoman period is analyzed in Necipoğlu 1990b, 140, 167 n. 25. For a discussion and selected illustrations of decorative patterns from the Timurid-Turkmen albums in Istanbul and Berlin, see Lentz and Lowry 1989, 189–233.

129. Golombek and Wilber 1988, 1: 117.

130. A celebrated passage of the fifteenth-century *Tāʾrīkh-i Khayrāt* (History of good works) describes the construction of Timur's Dilgusha Palace in Samarqand as a process in which the erection of the wall fabric and its decoration proceeded simultaneously as interrelated operations. As soon as the walls began to rise, decorators specializing in various crafts came to apply the revetments. See O'Kane 1987, 34; Golombek and Wilber 1988, 1: 91–93.

131. See O'Kane 1987, 41. Timurid-Turkmen master builders seem to have started out their careers in one of the building crafts, a training particularly relevant in an architectural tradition that thrived on decorative effects. Architects of the Ilkhanid period interchangeably used the titles of mason (*bannāʾ*), geometer-engineer (*muhandis*), and stucco worker (*jiṣṣāṣ*) in their signatures. This suggests that they too rose from the ranks of the building crafts. For these signatures, see Blair 1986, 39–41.

132. Even the stone-based Mediterranean tradition of Ottoman architecture, where decoration plays a much more restrained role, required chief architects such as Sinan to design appropriate decorative programs for each project; see Yenişehirlioğlu 1985; and Necipoğlu 1990b, 154–58.

133. For the element of theatricality in Timurid art and architecture, see Lentz and Lowry 1989.

134. It would be useful to analyze individual Timurid-Turkmen monuments in terms of the relationship of geometric schemes used in their ground plans, vaulting, and surface revetments. Such analyses can lead to a better understanding of the relative success or failure of geometric harmonization in specific cases.

PART 2. THE DISCOURSE ON THE GEOMETRIC "ARABESQUE"

That thou canst never end, doth make thee great,

And that thou ne'er beginnest, is thy fate.

Thy song is changeful as yon starry frame,

End and beginning evermore the same;

And what the middle bringeth, but contains

What was at first, and what at last remains.

—Goethe, "Hafis Nameh"[1]

CHAPTER 4. ORNAMENTALISM AND ORIENTALISM: THE NINETEENTH- AND EARLY TWENTIETH-CENTURY EUROPEAN LITERATURE

A great deal has been written about the geometric ornament of Islamic architecture without taking into consideration the role pattern scrolls played in the conceptualization and transmission of the distinctive mode of design that came to be known as the *girih* in the Persian-speaking eastern Islamic lands. This chapter will analyze the nineteenth- and early twentieth-century European literature on ornament within which the discussion of Islamic geometric patterns often was embedded. That literature generally overlapped with the Orientalist discourse on the so-called arabesque, singled out as a unifying essence of Islamic visual culture. After tracing the development of the ahistorical discourse on the arabesque, a category to which Islamic geometric patterns belong as a subset, I will turn to some of the recent secondary literature that uncritically has appropriated many of the stereotypes constructed more than a century ago, recycling them with a new ideological twist. This critical review of dominant paradigms in modern scholarship will serve as a backdrop for the subsequent parts of the book where the *girih* mode is historicized and contextualized.

Although the European fascination with Islamic ornament had its roots in the medieval and Renaissance periods, it reached its peak in the nineteenth century.[2] A lively debate on the subject of ornament arose in the wake of the Industrial Revolution when theorists began to reflect on the nature of abstract patterning as a language of pure form and color. Ornament, which was to be relegated to a distinctly lower realm by the Modern Movement and rediscovered by postmodernism, thus came to play a central role in the critical discourse on design in nineteenth-century Europe. As the practical relevance of abstract Islamic patterns to the European search for appropriate decorative motifs for mass production became apparent, publications on this specialized subject rapidly multiplied.[3]

Another factor that fueled the growing European interest in the decorative aspects of the Islamic architectural tradition was the awakening of the Romantic spirit with its search for the picturesque. The Romantic movement encouraged not only Gothic archaeology but also the exploration of exotic lands. James Cavanah Murphy, for example, one of the early architect-antiquarians interested in Gothic architecture, was equally fascinated with the monuments of Islamic Spain as can be seen in his *The Arabian Antiquities of Spain* of 1813–1816. The topographic illustrations of late eighteenth- and early nineteenth-century publications on various regions of the Islamic world, no doubt an outgrowth of earlier travelogues, accentuated the scenic decorative values of architecture so appealing to Romantic sensibilities. These idealized images depicted picturesque monuments, often set in the midst of idyllic landscapes with ruins and inhabited by languid natives wearing exotic local costumes.[4]

In the multivolume work written by orders of Napoleon, *Description de l'Egypte,* 1809–1828, illustrations of Islamic buildings were once again shown with natives engaged in a variety of activities, but this encyclopedic work reflected a more "scientific" ambition to record, catalog, classify, and ultimately control the recently colonized lands of Egypt. It was followed by several publications on Egyptian Islamic architecture, such as Pascal Coste's *Architecture arabe; ou, Monuments du*

Kaire, mesurés et dessinés, de 1818 à 1826, 1837–1839; Philibert Joseph Girault de Prangey's *Monuments arabes d'Egypte, de Syrie et d'Asie Mineure dessinés et mesurés de 1842 à 1845,* 1846; and Achille-Constant-Théodore-Emile Prisse d'Avennes's *L'art arabe d'après les monuments du Kaire depuis le VIIe siècle jusqu'à la fin du XVIIIe,* 1869–1877; followed by his *La décoration arabe,* 1887. In contrast to earlier travelogues these were lavish oversize volumes that often included color plates highlighting the polychromy of Islamic architectural revetments; they featured more precise measured drawings, plans, and elevations, accompanied by a large number of details and ornamental panels.

Like Napoleon's *Description de l'Egypte,* these publications generally started with an introduction to Egypt's geography, climate, and the various races making up its population, followed by an enumeration of the Islamic dynasties that ruled there until the time of the French expedition, before turning to a description of the monuments illustrated in accompanying plates. This methodological framework, based on the widespread nineteenth-century view that architecture and the decorative arts were determined by climate and racial character, turned the documented buildings depicted with natives into objects for the ethnographic "gaze." Coste, for instance, asserted in his introduction that monuments not only were adapted to different climates but also reflected the customs and the predominant racial character of peoples; in the case of Cairo this was "*la peuple arabe.*"[5]

Prisse d'Avennes wrote that the Muslim civilization of Cairo was engendered by the Koran, "a faithful embodiment of the aspirations, ideas, and mores of the Semitic races, and manifest sanction of customs appropriate to their character." He regarded the differences of style "in the works of the various races under the sway of the law of Muhammad" as "varied modes of the same art, since all the principles that inspire these races are derived from the same source." He concluded, "thus we affirm that it is to this pure source that we must turn if we are seriously to study Arab art," that is to the "Arab genius in architecture" that produced the monuments discussed in his book, their decoration, and "their capricious ornaments known as *arabesques,* down to the smallest details of their furnishings." Prisse d'Avennes ultimately hoped that the contents of his book would provide the "modern decorative arts and architecture materials with which they may renounce banality."[6] This practical agenda was reflected in his book's illustrations, which are dominated by architectural fragments and details of abstract ornamental panels presented out of context so that contemporary designers could derive lessons from them.

Albert Gayet's *L'art arabe,* 1893, argued that the abstract decoration of Arab monuments reflected deeply seated racial characteristics: "This is not the art of a religion or of a people, but that of a race." According to Gayet, the Islamic prohibition of figural representation had only reinforced the instinctive artistic tendency of Semitic races to renounce mimetic art. The innate spirituality and mysticism of the Arabs made them favor abstract ornaments capable of expressing transcendental beauty: "Contemplative and ecstatic, the Arab distances himself from the human form, not to obey a religious precept, but an instinct."[7] The spiritual essence of Arab art was embodied in the arabesque, with its three types of rhythmically interlaced variants, vegetal, calligraphic, and geometric.[8] First appearing in the ninth-century Tulunid monuments of Cairo, this mode of abstract ornament developed more fully during the Fatimid period in the tenth and eleventh centuries. Gayet identified the use of geometric compositions dominated by polygons as the "essential character of all Islamic art," even though he recognized regional variations reflecting racial differences.[9]

The arabesque came to be identified as the primary characteristic of Islamic art by Orientalists focusing on the material culture of the Arabs in Syria, Egypt, North Africa, and Spain during the nineteenth century, when artistic styles very often were defined as reflections of racial and religious mentalities.[10] The presence of figural imagery, whether in architectural decoration, objects, or manuscript painting, was conspicuously downplayed in constructing the "otherness" of the Arabo-Islamic visual tradition. Generally classified in terms of its geometric, vegetal, and calligraphic variants, the so-called arabesque (occasionally intertwined with stylized figures and animals) was assigned a purely decorative function that differed fundamentally from the iconographic tradition of

Western representational art.[11] The arabesque's alleged absence of meaning facilitated its appropriation by modern European architects and industrial designers.

Much like the publications on Egypt those on Islamic Spain, such as Jules Goury and Owen Jones's *Plans, Elevations, Sections and Details of the Alhambra,* 1842–1845, and Girault de Prangey's *Essai sur l'architecture des Arabes et des Mores en Espagne, en Sicile, et en Barbarie,* 1841, featured lavish plates of architectural monuments and ornamental details. Jones, who had first visited Cairo and Istanbul before moving on to Spain, identified the architecture of the Arabs as "essentially religious—the offspring of the Koran," just as Gothic architecture is of the Bible:

> The prohibition to represent animal life, caused them to seek for other means of decoration,—inscriptions from the Koran, interwoven with geometrical ornaments and flowers, not drawn decidedly from nature, but translated through the loom; for it would seem that the Arabs, in changing their wandering for a settled life,—in striking the tent to plant it in a form more solid, had transferred the luxurious shawls and hangings of Cachmere, which had adorned their former dwellings, to their new,—changing the tent-pole for a marble column, and the silken tissue for gilded plaster.[12]

This description of abstract Arab ornament in terms of three dominant elements (calligraphy, vegetation, and geometric interlaces) originating in nomadic tents would be repeated in countless publications including Gayet's *L'art arabe,* which sees the distant memory of tents in polygonal geometric patterns.[13]

Unlike the more scholarly first volume of Goury and Jones's *Alhambra,* which was accompanied by the Spanish Arabist Pascual de Gayangos's historical account and transcriptions of Arabic inscriptions translated into English and French, the second volume consists only of chromolithographic plates depicting decorative fragments detached from their architectural setting. It primarily was intended, much like Girault de Prangey's *Choix d'ornements moresques de l'Alhambra,* 1842, to supply contemporary designers with examples of ornament to copy or study. Most books that dealt with Islamic architecture in those years, such as Charles Félix Marie Texier's *Description de l'Asie Mineure,* 1839–1849, and his *Description de l'Arménie, la Perse et la Mésopotamie,* 1842; Coste's *Monuments modernes de la Perse,* 1867; and Léon Parvillée's *Architecture et décoration turques au xv^e^ siècle,* 1874, featured plates of decontextualized architectural ornaments in various techniques and styles, explicitly or implicitly addressing a European professional audience in an age of eclecticism and revivalism. Broken down into their decorated components such as facades, domes, minarets, portals, mihrabs, lattices, and calligraphic or ornamental panels, Islamic buildings were fragmented in these publications into reusable parts, displayed as neutral objects of "consumption."[14]

The implied practical agenda of these regionally specialized publications was articulated more explicitly in the European universal encyclopedias on ornamental styles. One of the earliest encyclopedias on ornament, Charles-Ernest Clerget and Martel's *Encyclopédie universelle d'ornements,* circa 1840, contained samples of Greek, Roman, Egyptian, Arab, Moresque, Persian, Turkish, Indian, Chinese, Japanese, medieval, Renaissance, and modern decorative patterns.[15] By far the most important and comprehensive encyclopedic work on this subject, Jones's *The Grammar of Ornament,* 1856, was written soon after the Great International Exhibition of 1851 in London, which encouraged a more rigorous grounding in the structural grammar of ornament. Jones classified Islamic ornament in terms of the ethnoracial categories typical of his time: Arabian, Moresque, Turkish, Persian, and Indian. This scheme, repeated in several later publications, distorted the multiethnic culture of most premodern Islamic dynasties, whose rule had unified several geographic regions with mixed populations and religious minorities. Together with the horizontal paradigm of an all-encompassing universal Muslim visual tradition, this vertical paradigm of regional ethnic dialects was among the lasting legacies of the nineteenth century in later scholarship on Islamic art and architecture.

The Grammar of Ornament was the first serious

study to adopt a systematic approach aimed at formulating a rational language of ornament appropriate for the modern industrial age. Its central assumption was that "evidence adduced from culture is as universal and timeless as evidence from nature; and that, therefore, decoration can be described by laws equivalent to the laws of science."[16] Jones's universalist tenet that the a priori conditions for good ornament were the same for all epochs and cultures was articulated in thirty-seven propositions. These propositions were meant as guidelines for an abstract language of polychromatic ornament going beyond historicisms and reflecting a protomodernist urge to establish universal rules for good design. Proposition 1 stressed the primacy of architectural form from which the decorative arts "arise" and upon which they are "attendant." Jones's conviction that despite "local or temporary character" all historic styles were based on "eternal and immutable" principles and on "the same grand ideas embodied in different forms, and expressed, so to speak, in a different language" was encapsulated in Proposition 36: "The principles discoverable in the works of the past belong to us; not so the results. It is taking the end for the means."[17]

Jones's practical agenda led him to overlook the signifying potential of ornamental patterns belonging to different cultural traditions so that their underlying syntactic principles could be appropriated for modern needs. It called for a study of patterns for their universal relevance rather than as systems of signification, at the expense of their cultural associations and contextual meanings. Jones's ahistorical approach to Islamic ornament was not different from the way in which he treated other ornamental styles, even though *The Grammar of Ornament* was heavily biased in favor of the so-called Moresque style epitomized by the Alhambra, "the very summit of perfection of Moorish art, as is the Parthenon of Greek art." The book assigned the more abstract Moresque and Arabian styles a higher status than the remaining three "mixed styles" (Turkish, Persian, and Indian), which were characterized by relatively naturalistic motifs. In his earlier monographic work on the Alhambra, Jones had already noted that the great variety of intricate Moresque patterns was derived from a series of underlying geometric grids providing infinite possibilities for the invention of abstract design. This was translated into a universal principle in Proposition 8: "All ornament should be based upon a geometrical construction."[18]

Jones was fascinated by the geometric basis of patterns in the Alhambra:

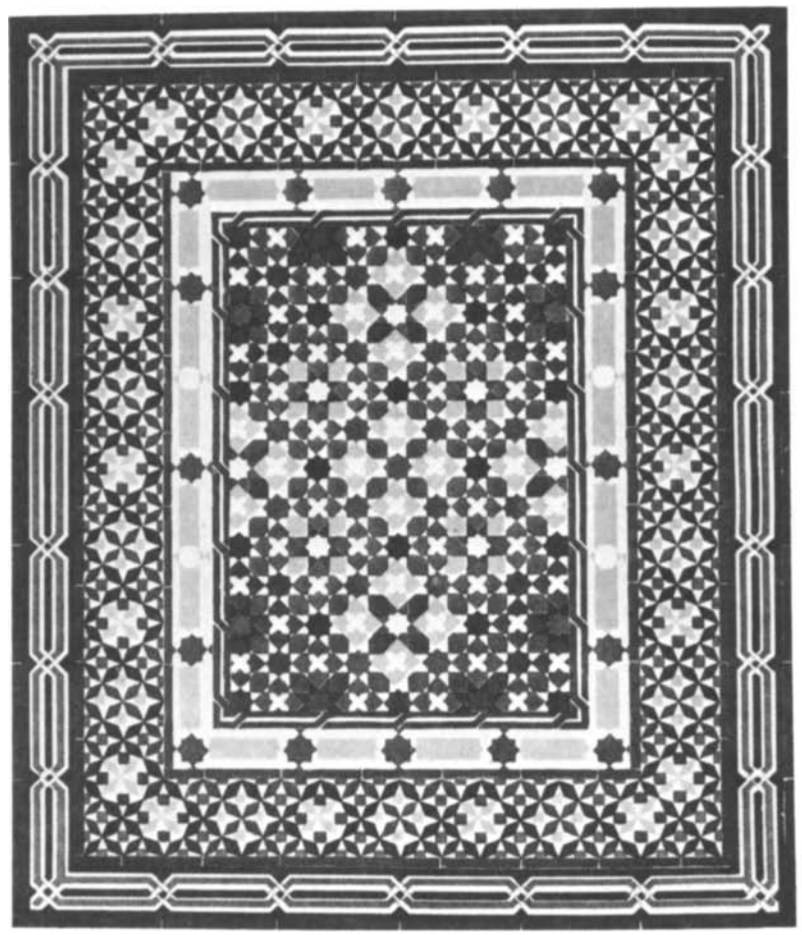
> However much disguised, the whole of the ornamentation of the Moors is constructed geometrically. Their fondness for geometrical forms is evidenced by the great use they made of mosaics, in which their imagination had full play. However complicated the patterns may appear, they are all very simple when the principle of setting them out is once understood. They all arise from the intersection of equidistant lines round fixed centres . . . in fact, geometrical combinations on this system may be said to be infinite.[19]

Though he did not explain these geometric principles of setting out patterns, which many later authors would attempt to decipher, Jones created polychromatic compositions inspired by Islamic and Pompeian geometric patterns that were generated by underlying grids. Intended for mosaics and tiles produced by modern mechanical processes, some of these drawings were published in his *Designs for Mosaic and Tessellated Pavements*, 1842 (fig. 78a). Others are preserved at the Victoria & Albert Museum in an unpublished volume of watercolor and ink drawings entitled "Designs for Mosaic Tiles" (fig. 78b).[20] These drawings reflect the genetic link Jones detected between two related historical styles of geometric design, a link he briefly hinted at in *The Grammar of Ornament*, which traces the roots of the geometric and vegetal arabesque to the Greco-Roman tradition.[21]

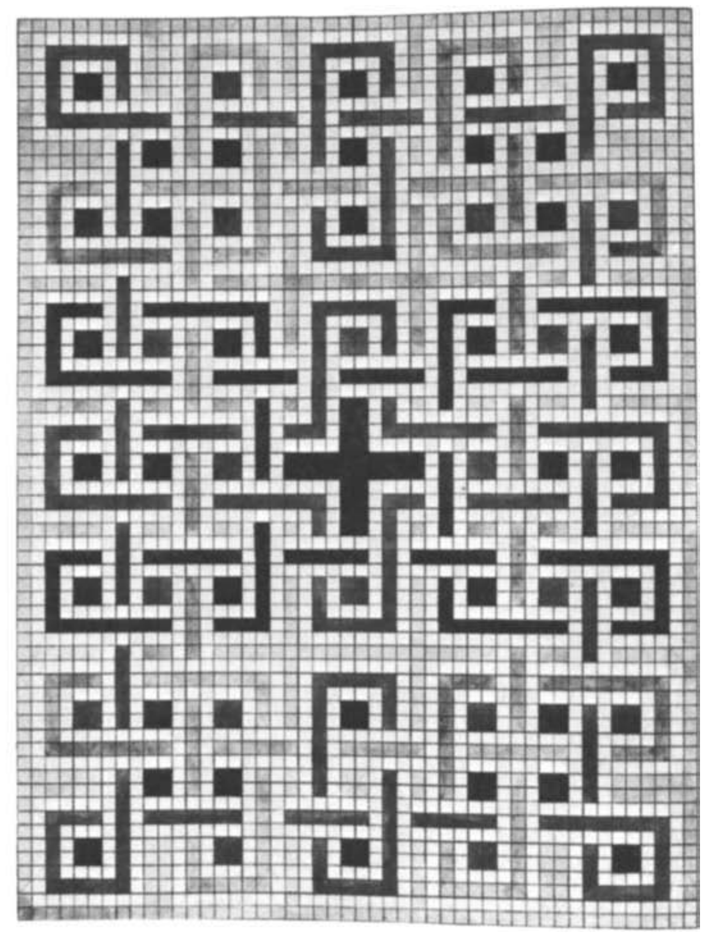
The classical origins of the arabesque were more fully explored in the Austrian art historian Alois Riegl's *Stilfragen*, 1893, which often cites Jones. In this celebrated study Riegl demonstrated in Darwinian terms the genetic mutation of the vegetal arabesque rooted in the classical palmette-and-

tendril ornament, only briefly discussing the origin of Islamic interlaced geometric patterns in late antique floor mosaics and ceiling decorations. He interpreted the arabesque as the creation of an "Oriental spirit of abstraction" (*orientalische Geist der Abstraktion*) that endlessly multiplied modular decorative units through "infinite correspondence" (*unendliche Rapport*) to cover whole surfaces in which foreground and background motifs were no longer distinguishable. Riegl noted that the transformation of Hellenistic, late antique, and Byzantine vegetal motifs into a "full-fledged Islamic arabesque" mode had been completed by the twelfth century after a turning point sometime around the tenth or eleventh century.[22]

Riegl's assumption that the arabesque played a purely decorative role was a product of his time just like his notion of artistic intention (*Kunstwollen*), a pervasive mentality (*Geisteshaltung*) or spirit (*Geist*) motivating the art of particular ethnic groups and periods. Like nineteenth-century Hegelian art historians who interpreted ornament—whether Greek, Roman, Gothic, or Islamic—as the reflection of a spirit, Riegl saw the arabesque as a mirror of cultural tendencies. It embodied an antinaturalistic drive for geometric abstraction that was an outcome of the Islamic prohibition against figural representation (*Bildverbot*). Its figure-ground ambiguities reflected a specifically Islamic weltanschauung that assigned absolute power to a transcendent God who leveled all hierarchies. The arabesque was thus the crea-



78a. Owen Jones, design for a mosaic pavement. From Jones 1842, pl. x. Photo: Courtesy John Calman & King, Ltd.



78b. Owen Jones, design for a mosaic pavement. From his volume of drawings "Designs for Mosaic Tiles," late 1830s or early 1840s, watercolor and ink on paper. By courtesy of the Board of Trustees of the Victoria & Albert Museum, London, Prints and Drawings Department.

tion of a *Kunstwollen* that transformed naturalistic classical motifs and brought them into a completely different cultural orbit.[23]

The Grammar of Ornament was followed by an avalanche of encyclopedic publications on ornamental styles that included chapters on Islamic patterns. Albert Charles Auguste Racinet's *L'ornement polychrome,* 1869–1887; Heinrich Dolmetsch's *Der Ornamentenschatz,* 1887; Leonhard Diefenbach's *Geometrische Ornamentik,* 1892; James Ward's *Historic Ornament,* 1897; and Alexander Speltz's *Ornamentstil,* 1904, are only some examples of this popular genre that continued well into the twentieth century until Modernism discredited the teaching of the syntax of historical ornament. These universal encyclopedias were complemented by specialized pattern books of Islamic ornament featuring plates with brief descriptions, such as E. Collinot and Adalbert de Beaumont's *Encyclopédie des arts décoratifs de l'Orient* (which in addition to the Hindu, Russian, Venetian, Japanese, and Chinese styles included *Ornements de la Perse,* 1880; *Ornements turcs,* 1882; and *Ornements arabes,* 1883); Nikolai Evstafievich Simakov's *L'art de l'Asie-centrale: Recueil de l'art décoratif de l'Asie centrale,* 1883; and the anonymous *Illustrations of Indian Architectural Decorative Work for the Use of Art Schools and Craftsmen,* 1887–1894.

Two books by Jules Bourgoin, *Les arts arabes,* 1873, and *Les éléments de l'art arabe: Le trait des entrelacs,* 1879, systematically analyzed for the first time the underlying compositional principles of geometric patterns, mainly selected from the Islamic monuments of Egypt. In the first book Bourgoin explained that he omitted the muqarnas (*les stalactites*) from his study of geometric patterns because he was addressing the contemporary needs of the industrial arts: "We had to conform to the conditions common to all publications of this genre, that is to say, we limited our subject in order to render the book more accessible by choosing among the materials we have collected those that appeared to us as the most appropriate for furnishing our industrial arts with new elements."[24] Bourgoin's focus on the compositional principles of two-dimensional geometric patterns reveals that the tendency to treat the muqarnas as an independent element (which eventually was singled out as the most distinctive artistic creation of Islam) originated in the nineteenth-century literature on ornament, a literature primarily concerned with surface patterns. This resulted in an arbitrary separation of spatial geometric constructs from the two-dimensional ones with which they are so consistently juxtaposed in Islamic pattern scrolls.[25]

Bourgoin's *Les arts arabes* begins with an introduction to the general characteristics of "the art of the Muhammedan East" (*l'art de l'Orient mahométan*) before turning to a structural analysis of planar geometric ornament, the main subject of the author's two books. Bourgoin and his contemporaries were writing at a time when factual information about Islamic architecture was rather limited. Painfully aware of these limitations, Bourgoin admitted that the Arab monuments of Egypt, Tunisia, Algeria, Morocco, Spain, and Sicily were better known to him than those of other Islamic countries from which more information had to be gathered. Moreover, he was not blind to stylistic variations between different regions and periods.[26] Nevertheless, like his contemporaries Bourgoin attributed a certain timelessness to the art of the Orient, often seen as an ethnographic rather than a historiographic field of inquiry. In *Les arts arabes,* where he used such categories as *race arabe* and *races sémitiques* or *sémitisées,* he wrote, "One should not expect to recover in the history of the art of the Orient the equivalent of that rigorous chain of different phases characteristic of the art of the Occident."[27] By casting the art of the Islamic East as a relatively static native tradition untouched by the historical processes so central to the complex evolution of European artistic culture, Bourgoin highlighted its essential otherness.[28] In doing so he repeated a topos of the Orientalist discourse, with its opposition between the rational West, representing a dynamic world of progress, and the spiritual East, constituting a static world of stagnation that was denied a true history.[29]

Like Jones before him, Bourgoin classified Arab ornament in terms of three elements—geometric, vegetal, and calligraphic—noting that "these three varieties are often mixed and mingled." Tracing the interlaced patterns (*entrelacs*) to late antique origins, he identified them as the essential characteristic of Islamic art in all regions.[30] Eugène-Emmanuel Viollet-le-Duc's introduction to *Les arts arabes* attributed the geometric abstraction

of such patterns, whose purity was diluted by naturalistic motifs in areas with a mixed population, to religious and racial factors:

> One has agreed to give the name "Arab art" to the art that has spread itself in those countries with milieus of diverse races through the conquest of Islam, from Asia to Spain. . . . This art excludes, if not in an absolute manner, at least generally, the representation of living beings, it thus limits its decorative conceptions to forms borrowed from geometry and to a lesser degree from flora, the latter also being subservient to geometric laws. It is especially among the semitic peoples that these tendencies manifest themselves with energy, at least since Muhammedanism. In places where a mixture of races exists, ornamentation partakes of diverse influences, and representations borrowed from organic nature intermingle with purely geometric compositions.[31]

Viollet-le-Duc repeated the generally shared view that the Arabs transformed the *entrelacs* of late antique art into a tapestry-like surface ornament because their nomadic origin inspired them to take the tent as a model for architecture.[32]

In *Les éléments de l'art arabe* Bourgoin identified three major styles of ornament—Greek, Arab, and Japanese (Chinese)—corresponding to the animal, mineral, and vegetable kingdoms of nature, respectively. With its rigid geometric basis Arab art was analogous to the crystallization of minerals; its nonfigural, abstract interlaced patterns, mechanically produced with the aid of ruler and compass, constituted an autonomous design system with closed horizons characterized by an incomparably "seductive" elegance.[33] In *Les arts arabes* Bourgoin defined this art form as essentially decorative, guided by the compositional logic of geometric schemes independent of observed nature and destitute of iconographic meaning: "One can consider Arab art as a system of decoration founded entirely upon the order of geometric forms and which borrows nothing or almost nothing from the observation of nature; that is to say, this art, very complete in itself, is destitute of natural symbolism and of ideal signification. The inspiration is abstract and the execution devoid of plasticity."[34]

The importance that the Islamic architecture of Spain and North Africa placed on surface decoration was judged by Bourgoin as a sign of inferiority.[35] Although he recognized the structural values of monuments in other regions, he nevertheless regarded Islamic architecture as essentially decorative. A similar view was expressed in the *Discourses on Architecture* by Viollet-le-Duc, who believed that studies of Islamic architecture would contribute to the progress of world architecture mainly in the field of decoration:

> The Arabs . . . did not change the Roman structure, but contented themselves with modifying its envelope; the geometry which they called to their aid did not lead them to discover new systems of construction, but simply inspired new curves for their arches, and was the generative element of all composition of ornament; in their hands it became a plaything, and occupied the eye with endless and marvelous combinations of lines. In the West, on the other hand, geometry at once overturned the Roman structure, which was no longer sufficiently scientific to meet the new emergencies of architecture. . . . In order that we may comprehend the differences between these two forms of art, both of which became the slaves of geometry, let us enter the Alhambra and examine there one of the last buildings due to what is called Arabic civilization. . . . In the Arabic monument, geometry supplied the vestment; in the western mediaeval structure, it gave the body.[36]

This comparison accentuated the essential decorativeness of the Arab architectural tradition, generally seen as the ultimate source of regional variants in other Muslim lands, and overlooked the structural values of such monuments as those of the Seljuqs, Ayyubids, and Ottomans. Its framing of Islamic architecture as a primarily decorative tradition, much like the lavishly illustrated nineteenth-century publications on that subject, embodied an implicit value judgment that associated decoration with femininity, as opposed to the

superior masculine vigor of structural forms. This dichotomy still dominates popular perceptions of Islamic architecture and the ongoing "feminization" of the Orient in various public media.

Viollet-le-Duc's introduction to *Les arts arabes* praised the difference of Bourgoin's analytical method from that of other publications with agreeable collections of engravings to skim through: "The book of Mr. Bourgoin is not merely one of those compilations of engravings pleasant to glance through, which adorn the libraries of architects and decorators, but which one never consults; it is a practical and complete treatise that uncovers in its entirety a new order of composition." Viollet-le-Duc, whose own studies emphasized the rational structural principles of Gothic architecture, appreciated how Bourgoin's analytical approach brought to light the formulas used in generating Arab geometric patterns, formulas that could be used in modern design practice. To be able to create anew, it was necessary to analyze the inner principles of forms rather than their outer appearance.[37]

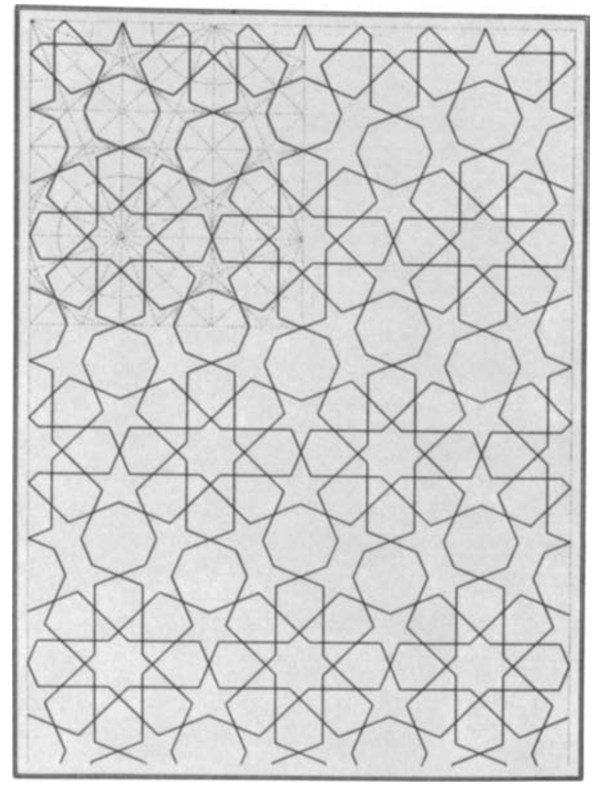
Viollet-le-Duc also praised Parvillée's *Architecture et décoration turques* as a corollary to Bourgoin's book. Both works sought rational geometric principles behind architectural forms and decorative motifs. His introduction to the Parvillée volume praised Bourgoin's and Edmond Duthoit's work demonstrating the geometric basis of ornament in the Islamic monuments of Cairo and Algeria, respectively. The three books had shown the rational scientific basis of seemingly fantastic compositions, to the dismay of the romantic "partisans of fantasy," who considered this a disastrous invasion of science into the domain of the arts. Speculating about the impact of the Arabic mathematical sciences on artistic production, Viollet-le-Duc wrote:

> Who does not know that the Arabs were versed in the mathematical sciences ever since an early period and that Occidental Europe partly owes them the elements of these sciences? It would be natural, therefore, to think that their artistic productions were based on this [scientific] knowledge, as far as it informed a perfectly clear-cut and sharply defined character [of forms]. Fantasy, or if one wishes imagination, could not have conserved in the domain of the arts such a unity across the centuries if formulas had not perpetuated themselves among the artists and artisans. The book of Mr. Parvillée is one of those works that introduces analysis into artistic productions that appear entirely fantastic, and which demonstrate that behind fairylike compositions cold science had intervened, that calculation had prepared the way. It is for this reason that we have claimed the privilege of writing this brief preface.[38]

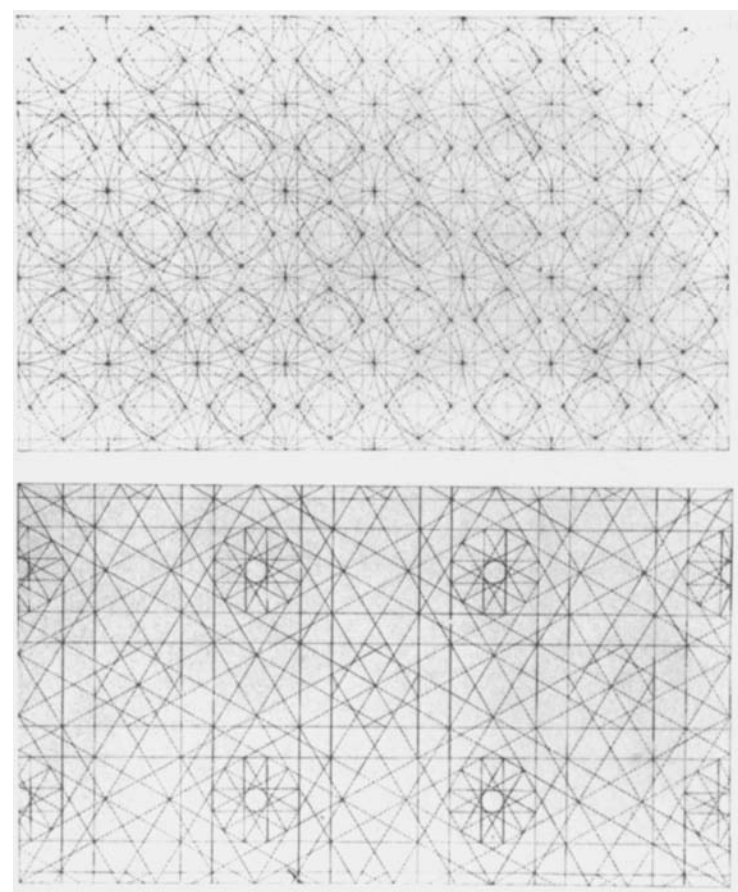
Prisse d'Avennes was the first to observe, in *L'art arabe,* that the unusually complex Islamic geometric patterns had to be based on a system of scientific knowledge transmitted by treatises on applied geometry:

> All ornamentation is based on geometric construction, that of the Arabs more than any other; thus, if one possesses the Elements of Euclid, one can trace, without instruction and, so to speak, without study, the most complicated of the interlace motifs of Cairo, Baghdad, or Granada. The Arabs had acquired such a taste for these plays of lines that several Arab treatises on geometry, analysed by Wroicke [Woepcke], contain problems of this type: "Trace six equal pentagons around a circle," and so on. For our part, we will refrain from presenting the general outline of Arab art in this domain, for that task has been masterfully performed by Mr. Bourgoin in his *Les arts arabes.*[39]

Bourgoin did not, however, research the historical methods of geometric construction by consulting such practical treatises. Neither did he have access to Islamic pattern scrolls that would have revealed the grid systems used in generating geometric patterns. The formulas he presented were based on his own observations and were not necessarily the same ones used by those who had originally created the patterns. Using a taxonomic method of classification according to inner structure rather than outer appearance, similar to that used by



79. Jules Bourgoin, star-and-polygon pattern superimposed with a diagram of its underlying grid network at the upper left corner. From Bourgoin 1879, fig. 51. Photo: Courtesy The University of California, Los Angeles.



80. Stuart Durant after David Ramsay Hay, designs with geometric grids. Based upon Hay 1844b, pls. XIII, 19. Photo: Courtesy John Calman & King, Ltd.

biologists, he subdivided patterns into eight categories based on the fundamental geometric elements that generated them (hexagons, octagons, dodecagons, star-rosette combinations of two types, square-octagon combinations, heptagons, and pentagons).

Bourgoin's systematic classification had a practical purpose; it addressed a European audience of practitioners. As Viollet-le-Duc's introduction to *Les arts arabes* stated, the book was intended to open up an infinite possibility of new geometric compositions, "applicable to architecture, as well as to woodwork, to painted ornaments, to cabinetmaking, to fine ironwork, to bronzes, to enamels, to textile designs, wallpaper, etc."[40] In *Les éléments de l'art arabe* Bourgoin reminded his readers that the book's two hundred drawings of two-dimensional geometric patterns, overlaid at the upper left corner with dotted construction lines showing underlying grids, would lose their apparent monotony when applied to various media and enlivened by color (fig. 79). A similar practice-oriented approach is found in the interior decorator and amateur scientist David Ramsay Hay's *Original Geometrical Diaper Designs*, 1844, a collection of Islamic-flavored interlaced geometric patterns meant to serve as underlying compositional grids for modern industrial ornament (fig. 80).

Bourgoin's studies of Arab geometric patterns were part of his broader inquiry into the syntactic structure of ornament as an abstract language. While a professor of the theory of ornament at the Ecole des Beaux-Arts in Paris he wrote one of the most original theoretical studies on geometric ornament, *Théorie de l'ornement,* 1873. This work attempted to formulate a universal system of repeat pattern and tessellation that would serve as a guide to the decorative arts. Like Jones, Bourgoin regarded the applied arts as subservient to monumental architecture and adopted a comparative approach to the major historical styles of ornament created by different races in order to uncover a syntax that transcended differing stylistic dialects.[41] He compared the "syntax" of ornament (consisting of order, rhythm, and scale) to prosody and defined the "grammar" of ornament as an ensemble of rules and procedures proper to each historical style characterized by distinctive forms.[42] His sophisticated protostructuralist analysis was rooted in the conviction that the decorative arts of the Industrial Age had to be based on a rational skeletal structure embodying measure (*la mesure*) and scale (*l'échelle*), constituting the shared basis of harmonious beauty in music, poetry, and ornament.[43]

Bourgoin's publications were followed by a series of others that studied the underlying generating principles of Islamic geometric patterns. One of them was Christie's *Traditional Methods of Pattern Designing,* which advocated the structural analysis of patterns: "The structural method, not the element used, is the sole basis of classification."[44] Christie's method followed "the lines laid down by the zoologist, who separates into well defined categories all living and extinct creatures."[45] His access to the Mirza Akbar scrolls

provided him with the original formulas used in setting out geometric patterns on various grid systems (see figs. 37–39). The repeat units of these Qajar scrolls supported Christie's universal definition of *pattern* as "a design composed of one or more devices, multiplied and arranged in orderly sequence."[46] The book gave many revealing examples of how Islamic geometric patterns were generated from modular repeat units by processes such as interlacing, branching, interlocking, and counterchanging. It did not, however, discuss the stellate arch-net and muqarnas vault patterns included in the Mirza Akbar scrolls, a conspicuous omission demonstrating that Christie was once again addressing a European audience of industrial designers, using a well-defined format in which three-dimensional patterning had no place.

Several regional studies on North Africa and Spain also analyzed geometric patterns in terms of their underlying structural grid systems, such as J. Collin's *Etude pratique de la décoration polygonale arabe,* 1911; Antonio Prieto y Vives and Manuel Gómez-Moreno's *El lazo: Decoración geométrica musulmana,* 1921; José Galiay Sarañana's *El lazo, motivo ornamental destacado en el estilo mudéjar, zu trazado simplicista,* 1943; and Basilio Pavón Maldonado's *El arte hispanomusulman en su decoración geométrica,* 1975.[47] Similar studies on geometric ornament by Soviet scholars were informed by the discovery of the Tashkent scrolls in the 1930s and of modern scrolls used by practicing Central Asian master builders. Such authors as Gaganov, for instance, worked out a structural syntax of planar geometric ornament for contemporary practitioners, classifying the repeat units (*rapport*) of *girih*s in terms of their symmetrical properties—linear or "ribbonlike," evenly spread or "carpetlike," and radial. Baklanov also observed that *girih*s were meant to be multiplied by "simple repetition," "symmetric repetition," or "rotation." This echoed a tripartite classification encountered in such European publications as Franz Sales Meyer's *Handbuch der Ornamentik,* 1888, which divided all planar geometric ornament into "ribbonlike forms (bands), bordered figures (panels), and unbordered flat patterns," or Alfred Dwight Foster Hamlin's *A History of Ornament, Ancient and Medieval,* 1916, which referred to "linear," "all-over," and "radiating" patterns.[48]

These parallels show that the aim of Soviet scholars was not so different from that of European encyclopedists of ornament who searched for a universal structural language that might have practical contemporary applications. This aim, already foreshadowed in Simakov's compilation of ornamental patterns in *L'art de l'Asie-centrale,* culminated in a large number of studies undertaken during the Soviet regime on the architectural ornament of Central Asian Islamic monuments. It is therefore not surprising that the fragmentary Tashkent scrolls initially were studied to derive practical lessons for contemporary usage; in 1941 Usta Shirin Muradov, Boris Nikolaevich Zasypkin, and N. S. Lukasheva wrote a textbook for artisans that was inspired by these scrolls.[49]

The emphasis of Russian publications on the rational-mathematical basis of architectural design and ornament in Islamic Central Asia prefigured recent attempts to apply scientific methods of analysis to the arts. The threefold classification of patterns used by such authors as Gaganov, Baklanov, Meyer, and Hamlin is not so different from that used today by crystallographers who scientifically analyze patterns in terms of their underlying symmetry groups. The latter identify three pattern types in plane designs: one-dimensional (line), two-dimensional (plane), and finite (point or radial). Bourgoin, who had observed the crystalline composition of Arab ornament, which reminded him of the inner structure of inanimate matter, would be surprised to find out that this analogy had a direct relevance for mathematicians investigating crystal symmetry. Edith Müller (a student of Andreas Speiser, who wrote *Die Theorie der Gruppen von endlicher Ordnung,* 1927, and *Die mathematische Betrachtung der Kunst,* 1944) was the first systematically to use the mathematical tools of group theory in the analysis of Islamic ornament. Her thesis, *Gruppentheoretische und strukturanalytische Untersuchungen der Maurischen Ornamente aus der Alhambra in Granada,* 1944, opened up new horizons for the scientific classification of geometric patterns on the basis of different symmetry groups.[50] Her work was followed by a number of studies on the arts, each study using categorization methods developed by crystallographers.[51]

Rigorous classifications derived from the mathematical bases for repeat patterns are found in

some recent books and articles that are modern counterparts of nineteenth- and early twentieth-century universal encyclopedias of ornament. The architect Peter S. Stevens's *Handbook of Regular Patterns*, 1981, for example, which illustrates the three plane pattern classes (point, line, plane) with examples selected from worldwide artistic traditions, familiarizes artists with the technical descriptions of crystallographers and chemists for a better structural understanding of repeat patterns that may help them create new designs. These recent studies replace the unscientific terms *decoration* and *ornament* with "pattern"; they refer to tightly fitting geometric figures in contact that leave no gaps as regular or semiregular "tessellations" (planar or spatial) and to underlying grids as "nets" or "lattices." Regarding earlier attempts at categorizing ornamental patterns by such authors as Bourgoin (who grouped them according to their geometric elements rather than their symmetry groups) as lacking in mathematical basis, modern-day scholars have adopted a detailed system of notation to standardize the mathematical study of repeat patterns called "tilings and patterns." Some of these studies focused exclusively on the crystallographic analysis of Islamic geometric patterns, singled out as a treasury for teaching such topics as tessellation, algebra, two- and three-dimensional symmetry, and color symmetry.[52]

Wasma'a K. Chorbachi, who since 1970 has been arguing for "the need for a scientific language and methodology with which to understand and systematically categorize Islamic geometric pattern," noted the necessity to "search for the proper scientific languages and tools to generate new forms and expressions" in contemporary Islamic design. She wrote:

> The importance of Group Theory and its notational system for Islamic art lies in the fact that it provides a tool for exact cataloging of the infinite number of geometric designs used in Islamic art. It is also helpful as an analytical tool in recognizing the symmetry used within a design. Moreover, it provides a precise language and terminology by which those who are interested in these patterns can communicate precisely with each other about these patterns. All this might seem redundant to the scientists who have been involved in the study of symmetry yet, for the art historians, it is still an unacknowledged tool.[53]

Such scientific studies provide invaluable insights into the fixed geometric properties of symmetry relationships and the constraints that designers faced in the composition of form and color. Their mathematical notation system enables the scientifically precise description and classification of geometric patterns, but such an enterprise falls beyond the scope of this book. The master designers who created the Topkapı scroll's variegated patterns were probably less concerned with the problem of classification than with the ingenious manipulation of inherited geometric formulas. Neither the ability to classify the symmetry groups of given patterns nor the structural analysis of their syntax in ornament studies (which only rarely approximate the original formulas used in pattern scrolls) explains the creative processes and aesthetic aspirations of their makers. Those processes relied on the transmission of a knowledge of practical geometry codified in pattern scrolls that provided master builders with a rich repertoire of traditional formulas developed over the centuries. An understanding of the historical methods of geometric design therefore requires a close study of surviving pattern scrolls, practical geometry manuals, and written primary sources relevant to the theory and praxis of the *girih* mode.[54]

Given that a large portion of the secondary literature we have considered in this chapter was directed to a Western professional audience not particularly interested in a study of Islamic geometric patterns per se, the general lack of concern for primary sources capable of revealing historical methods and processes of design is not so surprising. The nineteenth- and early twentieth-century European discourse on ornament, characterized by its urge to find universal design principles, overlapped the equally ahistorical discourse of Orientalism, with its essentialist fixation on the arabesque. It was these two types of discourse in which the earliest discussions of Islamic geometric patterns were most often embedded.

CHAPTER 5. RECENT STUDIES ON GEOMETRIC ORNAMENT

From the early twentieth century onward the study of Islamic art and architecture developed into a specialized academic field in which Orientalist, archaeological, and museum or collections research led to an unprecedented accumulation of information. Corpuses of epigraphy, archaeological reports, international exhibitions, detailed regional studies, and surveys with a general scope, either limited to a particular period or covering the whole range of Islamic art and architecture, increased awareness of the chronological, regional, and ideological complexities of the Muslim visual heritage. These academic studies, which grew out of the Orientalist discourse, increasingly turned away from the ethnoracial categories encountered in nineteenth- and early twentieth-century writings and replaced them with regional, dynastic, and chronological-stylistic ones. Nevertheless the notion of an all-encompassing category of "Islamic" art continued to dominate scholarship. Such subcategories as Arabic, Moorish, Turkish, Persian, Central Asian, or Indian generally were reclaimed by various nationalist discourses that attempted to construct new self-identities confined to the borders of modern nation-states that no longer corresponded with those of previous dynasties encompassing multiple regions, nations, and subcultures. Despite the growing refinement and sophistication of academic art-historical studies, the Orientalist legacy still lingered.

Specialized publications dealing with the subject of architectural decoration were now for the most part limited to particular techniques, motifs, periods, or regions. Generously illustrated popular works such as Sonia P. Seherr-Thoss's *Design and Color in Islamic Architecture,* 1968, and Derek Hill and Oleg Grabar's *Islamic Architecture and Its Decoration, A.D. 800–1500,* 1967, however, signaled that the earlier interest in a broader treatment of ornament had not altogether disappeared. Nevertheless with the advent of international Modernism in architecture, the popularity of universal encyclopedias of ornament eventually died out. The genre of professional pattern books with Islamic material was, however, curiously revived in the 1970s in response to the new Middle Eastern construction boom, particularly in Iran and the Arab lands, that made both Western and non-Western architects competing for projects search for ready-made prescriptive formulas. It was in that context that Bourgoin's *Arabic Geometrical Pattern and Design* was reprinted in 1973, accompanied by several new publications on the subject of Islamic ornament that emphasized geometry.

In an attempt to "Orientalize the Orient" these publications willfully blurred stylistic, regional, and chronological differences unknown to earlier writers. Constructing the artistic "otherness" of the Islamic East was no longer a project limited to Europeans observing a foreign culture. Now a mixed group of Western and non-Western authors sought to articulate that "difference" in response to the postcolonial Islamic world's internal search for distinctive national and cultural identities.[55] In doing so they ironically appropriated many of the stereotyped categories constructed by the nineteenth-century Orientalist discourse, among which the so-called geometric arabesque came to enjoy a particular prominence, a striking example of Orientalism in reverse. The new literature on the arabesque was often framed by an explicitly or implicitly antimodernist discourse that sought to

preserve the "otherness" of the Orient, with its timeless traditions rooted in an innately spiritual psyche. This represented a reversal of the proto-modernist search of earlier writers such as Jones and Bourgoin for universal design principles transcending historicisms, an urge that would ultimately culminate in the rejection of historical ornament by international Modernism. By contrast, the new writers on Islamic ornament exhibited a revivalist nostalgia for the architectural styles of the past in a modern world whose secular internationalism seemed to threaten the distinctiveness of traditional Muslim culture. A recurrent subtext of the new secondary literature on geometric ornament was a critique of the modern world and the spiritual plight of Muslims in an industrial era dominated by Western culture.

This chapter will analyze the ahistorical treatment of Islamic geometric patterns in some recent publications, particularly the series of books that appeared in conjunction with the World of Islam festival in 1976 in which the arabesque was once again singled out as the primary "essence" of Islamic visual culture. No longer limited to regional studies on Egypt, Syria, North Africa, or Spain, these publications universalized the so-called arabesque into a pan-Islamic concept transcending time and space. Before turning to the books published as part of the festival, I will briefly summarize the various definitions of the arabesque current at the beginning of this century that prepared the groundwork for later studies.

The entries on the arabesque in the two editions of the *Encyclopaedia of Islam* encapsulate the prevalent views. Ernst Herzfeld's entry of 1913 added a fourth, figural category to the three more common variants of the arabesque, that is, vegetal, geometric, and calligraphic:

> The term arabesque in its wider sense, as denoting the ornament of Muslim art in general, also comprises a number of figurative elements. It would indeed be possible to distinguish these from the arabesque, taking this word in a narrow sense, and to class them under the term "iconography"; but the value of these figurative elements is for the most part purely ornamental, while their composition is frequently closely connected with or even inseparable from the arabesque.[56]

Herzfeld noted the antinaturalism and geometric abstraction of the arabesque, characterized by "countless repetitions" and an "infinite correspondence" that gave rise to completely covered surfaces reflecting a typically Islamic horror vacui, a psychological fear of empty spaces.[57] This notion would be repeated by such authors as Richard Ettinghausen and by Maurice S. Dimand, who wrote, "Mohammedan art is essentially one of decoration, for an empty surface is intolerable to the Mohammedan eye."[58] Like earlier writers Herzfeld associated the arabesque, identified as a "dominant feature of supreme authority for the whole art of Islam," with the "character of the Muslim view of life":

> All provincial developments, apart from a few exceptions, change the style of the arabesque in its outward features only. The essential characteristics of the arabesque are preserved throughout, both as regards the composition and the elements; there is therefore only one arabesque in antiquity as well as in modern times, in the East and the West, and in the South as well as the North.[59]

Ernst Kühnel's "Arabesque" entry in the second edition of the *Encyclopaedia of Islam,* 1960, summarized his booklet *Die Arabeske,* 1949, translated into English in 1976 by Ettinghausen as *The Arabesque: Meaning and Transformation of an Ornament* (published in 1977). Rejecting Herzfeld's broad description of the arabesque as "antiquated," Kühnel adopted Riegl's narrower focus in *Stilfragen* on its vegetal type that could be intertwined with geometric, calligraphic, and stylized figural elements. He traced the origins of the arabesque to late antiquity and noted that it had acquired its typical shape in the ninth century under the Abbasids, becoming more fully developed in the eleventh century under the Seljuqs, Fatimids, and Moors, thereafter appearing in countless variations impossible to classify "according to a chronological order or according to national-dynastic predilections." Though "Persian, Turkish and Indian artists understood the language of the arabesque quite as well as Arabic-speaking artists," Kühnel interpreted this mode of design as the "outcome of a particular Arab atti-

tude" that informed parallel developments in Arabic poetry and music, as noted in Johann Wolfgang von Goethe's (1749–1832) *West-Östlicher Divan,* 1820. Kühnel identified its two aesthetic principles as "rhythmical alternation of movement always rendered with harmonious effect, and the desire to fill the entire surface with ornament." Like most earlier European writers on the subject, Kühnel highlighted the purely ornamental character of the arabesque: "It seems unnecessary to emphasise that the arabesque never has any symbolic significance but is merely one ornament from a large stock."[60] Its ephemeral decorative quality and its lack of iconographic specificity is stressed in *The Arabesque:*

> Just as the infinite repetition underlines the significance of the individual forms which do not come into sharper focus through serialization, but rather seem to evaporate, so does the uninterrupted covering of the surface deprive them of all objective meaning. It is obviously the decorative intention that the eye of the viewer is not arrested by the pleasant detail, but that it is delighted by the kaleidoscopic passing of an ever-changing and disappearing harmony of unreal forms. . . . One would entirely misunderstand the character of the arabesque if one were to attach to it any symbolic function. . . . Decisive is a decorative intent which is devoid of a meaningful purpose.[61]

Like Riegl, Kühnel related the development of the vegetal arabesque to an Islamic spirit, specifically to the concept that "nature does not create out of itself, but that it is the work of the divine creator which manifests itself in all happenings and phenomena." The belief in the transitoriness of the world led "to the assumption that it cannot be the task of the artist to arrest reality which has been optically perceived or personally experienced since it could be counter to the divine decision to give permanence to temporary earthly forms."[62] Thus the divinely inspired artist who "carried in himself the Islamic world view" deliberately reworked naturalistic motifs into unreal forms that gave free reign to the artistic imagination "plunged into linear speculations of an abstract nature."[63]

Such Orientalist scholars and art historians as Louis Massignon, Georges Marçais, and Ettinghausen also explained the characteristics of abstract ornament by reference to the nature of Islam. Massignon, for example, linked the ephemeral abstractions of Islamic art with the philosophy of atomism, according to which the universe was composed of atoms and accidents continually changed by an omnipotent God, unique and indivisible. Although this hypothesis is not unlikely, as we shall see in part 3, Massignon failed to historicize it, presenting it as a universal explanation regardless of context.[64] The questions raised about abstract Islamic ornament by Massignon, Ettinghausen, and others including Herzfeld, Dimand, and Kühnel were put into perspective in Grabar's *The Formation of Islamic Art,* 1973, which devoted a chapter to "Early Islamic Decoration: The Idea of an Arabesque." Here Grabar discussed the methodological problem of assigning meaning to repetitive abstract patterns that did not "seem to have an intellectual or cultural content" but to have been aimed at "beautification" and "visual pleasure."

Grabar observed that the arabesque, in which every motif, even inscriptions, became "ornamentalized," endowed the observer with considerable subjective freedom, given its "ambiguity" and "ambivalence." Iconographic significance could occasionally be assigned to it (especially through the use of inscriptions), but an essential ambiguity still remained: "Like the beads of the holy man, the meditation it suggests is not in itself but in the mind of the beholder." Grabar did not altogether dismiss the possibility that "Muslim ornament could not reflect some attitude of Islamic culture as a whole," comparable to the relationship between Scholasticism and Gothic construction; "the mood of the faith and the mood of the ornament" seemed to share a number of common assumptions. However, doubts about the validity of such parallels lingered. He concluded, "It does not seem possible to formulate for early Islamic times any sort of correlation between a common denominator of the arts and what appears to have been the main common denominator of the contemporary society."[65]

Some other scholars were apparently less troubled by the methodological problems of assigning specifically Islamic meanings to abstract patterns. Foreshadowing several later Muslim authors on the subject, Ismaᶜil R. al-Faruqi accused West-

ern scholars of misinterpreting Islamic art as merely "decorative" and "contentless," thereby failing to understand its "spirit" and its "Islamicness." He argued that denaturalized abstract forms visually represented God's "infinity or inexpressibility" and the Muslim profession of faith, "There is no God but God." The Islamic artistic tradition, stamped by the "Semitic consciousness" and by the central notion of "*tawḥīd*" (absolute unity or oneness of God), induced "an intuition of unimaginableness and inexpressibility—in short, of infinity."[66] Al-Faruqi defined the arabesque as follows:

> Properly understood, the Arabesque is the religious work of art in Islam. It is the semitic religious work of art *par excellence* since it produces an aesthetic—not logical—intuition of "not-nature," of "not-finitude," and of "inexpressibility," the only intuitable categories of transcendent reality. Every work of art in Islam is a more or less successful exemplification of it.[67]

Asserting that figural representation is against "the vision of *tawḥīd* as expressed in the *shahāda* [profession of faith]," al-Faruqi dismissed miniature painting as originating from "non-Islamic" influences. He assigned priority to architecture and the arabesque, since "figural painting is of miserably less value" to the Muslim whose consciousness is "completely determined by Allah" and by the notion of *tawḥīd* that is "the first principle of every aspect of Islamic civilization." The abstract forms of Islamic art, therefore, have no function other than helping the believer intuit "the unintuitability of that which can never be the object of immediate intuition," that is, the absolute transcendence of a God who is beyond time and space.[68]

Other interpretations that stressed the Islamic meanings of the arabesque tended to highlight its mystical, Sufi dimension. This dimension had already been emphasized in Gayet's *L'art arabe*, 1893, where polygonal geometric interlaces were seen as mystical expressions of transcendental beauty, inviting the soul to contemplation and ecstasy. The same idea appeared again in Probst-Biraben's "Essai de philosophie de l'arabesque," 1905, where abstract patterning is defined as "the ornamental translation of mystical Muslim thought, its very symbolism." This act of translation was undertaken by Muslim artisans belonging to Sufi confraternities who exalted their spiritual meditations by visually transcribing them on the walls of buildings and on the surfaces of luxury objects by means of an ornamental language.[69] The rhythmic repetition of abstract patterns recalled the ritual of *dhikr*, the tireless repetition of ejaculatory litanies by the devotees of mystical brotherhoods. Probst-Biraben wrote:

> Gayet, an artist and fine connoisseur, has perhaps exaggerated the symbolism of interlaced patterns [*entrelacs*], but has finely sensed the spirituality of Arab inspiration, the connection of art with the Muslim mystic desirous of tracing phenomenal multiplicity back to the divine unity, and the emanation back to the initial source.[70]

The mystical notion of "unity in variety," as reflected in the cosmological order of the universe, and the doctrine of *tawḥīd* came to occupy a central position in the interpretations of the arabesque during the 1960s and 1970s, culminating with the publications of the World of Islam festival. The role of Sufism, the esoteric dimension of Islam, was particularly emphasized in Nader Ardalan and Laleh Bakhtiar's *The Sense of Unity: The Sufi Tradition in Persian Architecture*, 1973. This book argued that "unity in multiplicity," a central doctrine of Sufism, is what informs all the elements of Islamic architecture in Iran, from geometric surface decoration and architectural form to complex urban settings. In the preface Seyyed Hossein Nasr defined the Iranian Islamic architectural tradition as composed of timeless "forms that echo transcendent archetypes" intimately related to cosmology and identified its most fundamental principle as the concept of God's unity (*tawḥīd*):

> There is nothing more timely today than that truth which is timeless, than the message that comes from tradition and is relevant now because it is relevant at all times. Such a message belongs to a now which has been, is, and will ever be present. To speak of tradition is to speak of

> immutable principles of heavenly origin and of their application to different moments of time and space. . . . Islamic civilization presents an eminent example of a traditional civilization wherein can be clearly observed the presence of certain immutable principles that have dominated the whole civilization in both time and space. Islamic art is no more than a reflection in the world of matter of the spirit and even of the form of the Quranic revelation.[71]

Nasr's emphasis on static tradition, as opposed to dynamic historical change, revived a central topos of the Orientalist discourse with its typical distinction between historical and traditional cultures. This topos was now reversed to privilege unchanging tradition over modernity and given a new coloring through the notion of the archetype, here applied to the analysis of Sufism. Notably the book's bibliography cited C. G. Jung and Mircea Eliade in addition to such scholars of Sufism as Henry Corbin and Toshikiko Izutsu.

After identifying the Islamic architecture of Iran as a spiritual tradition, Nasr pointed out that "this art has been only too rarely studied with the aim of understanding its symbolic and metaphysical significance." To penetrate its inner meaning "woven around the central doctrine of unity" required "both an outward research and an inner discovery of the tradition," not unlike a spiritual journey toward truth. Complaining that the "modernized classes of the East since the spread of the modern mentality from the end of the last century" have ignored their own architectural traditions, Nasr recommended the book to the Westernized practicing architects of Iran "at a moment when so many of them are looking desperately for guidelines to follow and have realized the shortcomings of imitating Western models blindly." Although the book's search for "primordial and eternally valid" design principles may initially recall the modernist search for universal forms transcending historicisms, it is nevertheless embedded in an antimodernist, traditionalist discourse.[72]

Ardalan and Bakhtiar interpreted geometric patterns as eternal archetypes that could lead the contemplative mind from outer appearances to the esoteric inner realities of Sufism through spiritual hermeneutics.[73] They wrote, "These shapes, as the personality of numbers, are understood by traditional man as aspects of the multiplicity of the Creator."[74] Infinitely extendable geometric patterns symbolized the inner esoteric dimension of Islam and the Sufi concept of the "inexhaustible multiplicity of creation, the effusion of Being that emanates from the One: multiplicity within unity."[75] Although this may have been true in some cases, the authors showed no attempt to contextualize their arguments or to demonstrate through primary sources the ways in which geometry was interpreted in specific historical settings. Their universalizing generalizations were based on conceptual categories freely borrowed from a wide variety of Sufi texts without regard to time and place, or to the cultural mechanisms that informed the assumed connection between visual aesthetics and Sufism.

The radical sectarian shifts throughout Iranian history (characterized by such irreconcilable positions as the rigid Sunnism of the Seljuqs and the official Twelver Shiʿism of the Safavids) were ironed out in this romantic vision of an eternal sense of unity that was engendered by an innate spiritual psyche, shaped by the unique Iranian ecology and tradition. Ardalan and Bakhtiar's epilogue promised a future Iranian artistic creativity that would be part of a tradition with no apparent beginning or end: "This body of knowledge crystallized through the arts, embodied in the traditional societies, and available today for those who would 'see,' presents concepts that are primordial and eternally valid."[76] What could be a more appropriate ending for a book published during the regime of Shah Riza Pahlavi "on the occasion of the twenty-fifth centenary of the foundation of the Persian Empire," as its title page stated, a book that rarely mentioned any specific dates that might disrupt the semblance of uninterrupted continuity in an unchanging traditional Iranian culture rooted in ancient civilization?

The central premises of *The Sense of Unity* were intimately linked with those of the Traditionalist School founded in Switzerland by René Guénon (1886–1951). Adherents of that school traced the so-called modern deviation to Renaissance secularism, engaged in a radical critique of the

contemporary world, and searched for universal spiritual truths in metaphysics, cosmology, and traditional art. The publications of Titus Burckhardt, a leading spokesman of this school who was to become a key figure together with Nasr in the World of Islam festival, are fully cited by Ardalan and Bakhtiar. Titus Burckhardt, the grandnephew of the celebrated Swiss cultural historian of the Renaissance, Jacob Burckhardt, was an intimate friend of Frithjof Schuon, another disciple of the Traditionalist School, who wrote on esotericism and the transcendental unity of religions. Burckhardt had converted to Islam after spending some years in Morocco as a young man in the 1930s, where (much like the early Orientalists) he developed a romantic fascination with traditional Maghribi culture that still preserved many premodern elements. There he became immersed in Sufism, a subject to which most of his early studies were devoted. These works dealt with esoteric Sufi doctrines (particularly those of the Andalusian shaykh Ibn al-ᶜArabi [1165–1240]), alchemy, astrology, cosmology, and spiritual symbolism in the traditional crafts.[77]

Burckhardt's main work on aesthetics, translated from the French as *Sacred Art in East and West,* 1967, discussed the metaphysical aesthetics of major world religions, including Islam. Among his early articles on Islamic aesthetics perhaps the most influential was "Perennial Values in Islamic Art," 1967, which argued for the timeless spiritual unity of the Islamic visual tradition in all periods and regions.[78] Noting that the arabesque prevented the observer from focusing on any one form, Burckhardt stressed its mystical, contemplative, and ahistorical character capable of bridging the Muslim past and present through abstract forms concerned with "only those elements that are valid for all time":

> There are two typical forms of the arabesque; one of them geometrical interlacing made up of a multitude of geometrical stars, the rays of which join into an intricate and endless pattern. It is a most striking symbol of that contemplative state of mind which conceives of "unity in multiplicity and multiplicity in unity." . . . The second form, the arabesque commonly so-called is composed of vegetable motifs, stylized to the point of losing all resemblance with nature and obeying only the laws of rhythm transposed into graphic mode, each line undulating in complementary phases, and each surface having its inverse counterpart. The arabesque is both logical and rhythmical, both mathematical and melodious, and this is most significant for the spirit of Islam in its equilibrium of love and intellectual sobriety. . . . Moreover, the universal character of geometrical ornament—the fundamental elements of which are essentially the same, whether they appear in a Bedouin rug or in a refined urban decoration—corresponds perfectly to the universal nature of Islam, which unites the nomads of the desert with the learned man of the city, and this latter-day epoch of ours with the time of Abraham.[79]

This extraordinary passage encapsulates Burckhardt's essentialistic approach to Islamic visual culture, an approach that informs his rejection of historical methods of analysis. He denounced the analytical method of modern art history as unequipped to deal with the spiritual dimension of Islamic art: "Whatever is timeless in art—and a sacred art like that of Islam always contains a timeless element—is left out by such a method."[80] The radical implication is that historical methods of analysis developed for post-Renaissance artistic traditions in the West are inappropriate for understanding the Islamic visual tradition. This tradition represented an ahistorical spiritual phenomenon accessible only to the initiated believer who can decipher its inner, esoteric meanings:

> The study of Islamic art, if undertaken with an open mind and without the post-Medieval prejudices we have mentioned, is a way of approach to the spiritual background of all Islamic culture. . . . The main shortcoming that one has to avoid is the academic mentality that considers all works of art from earlier centuries as purely historical "phenomena" which belong to the past and have very little to do with present life. . . . Let us ask what is

> timeless in the art of our spiritual ancestors. If we recognize this, we shall also be able to make use of it within the inevitable framework of our own age.[81]

This statement, based on the premise that Islamic culture constitutes a monolithic block characterized by its timeless continuum between the seventh and twentieth centuries, puts the modern Muslim observer in the privileged position of "native informant." The implication that Muslim believers are better equipped to penetrate the inner meanings of their own visual culture assumes that the past is more transparent to them. Since all interpretations are bound up with one's own historicity, however, it is difficult to believe that any interpreter, from whatever background, is more privileged with objectivity. A sensitive contextual interpretation of any given aspect of the Islamic visual tradition as a historically informed, dynamic cultural phenomenon demands equal methodological rigor in the use of primary sources from any scholar engaged in that field, whether Muslim or non-Muslim. The construction of a visual tradition based on timeless spiritual truths, however, makes such methodological rigor irrelevant. Burckhardt stated that the Islamic visual tradition was fundamentally derived from the contemplation of divine unity (*tawḥīd*) revealed in the Koran in discontinuous flashes: "Striking the plane of the visual imagination, these flashes congeal into crystalline forms, and it is these forms in turn that constitute the essence of Islamic art."[82]

Disregarding the specificities of the historical and regional developments of Islamic theology and mysticism, Burckhardt and the authors of *The Sense of Unity* attributed a universal significance to Sufism, which was not equally influential in all regions or periods. Neither the doctrine of *tawḥīd* nor the transience of the material world, in whose diverse forms the contemplating believer could detect underlying signs of transcendental unity, were concepts limited to Sufi circles. It is therefore not surprising that such authors as al-Faruqi and Edward H. Madden associated abstract Islamic patterns with Sunni orthodoxy instead of Sufi esotericism. Nasr's claim that "to grasp fully the signification of Islamic art is to become aware that it is an aspect of the Islamic revelation, a casting of the Divine Realities (*ḥaqā'iq*) upon the plane of material manifestation" could even be regarded as anathema from an orthodox Muslim viewpoint.[83] Given the completely transcendental nature of the creator it would be inconceivable for an orthodox believer to attempt to represent God or God's revelation in any form, no matter how abstract. This is why al-Faruqi interpreted abstract patterns as visual expressions of the nonrepresentability of God, rather than as material manifestations of spiritual truths accessible to the contemplating mystic.

Madden, who recognized that arabesques and "infinite patterns" were not uncommon in Sufi or Shiʿi settings where they "could well be given various esoteric meanings," nevertheless associated them primarily with "the classical Sunni Muslim world view" that blended "traditional legalism and moderate mysticism." He concluded that such patterns:

> though used in the other contexts, seem especially Sunni in perspective, for they speak eloquently of no individual, no unit, no person, no historical event but rather of the infinite, transcendent One. Sunni Islam in its purest form is a lovely and lonely world view; the infinite pattern and the arabesque in their purest forms mirror that world view in a transcendentally beautiful way.[84]

Although Madden deemphasized the Sufi dimension of Islamic art, his views were nevertheless rooted in the same Traditionalist School that inspired Burckhardt and Nasr:

> Traditional or religious art is the expression of a whole community, of a complete culture, in contrast to the idiosyncratic and self-expressive features of contemporary art and, indeed, of much of Western art since the Renaissance. Decoration is fundamental to all traditional art, but it is always symbolic in nature and never something added as an afterthought. In Islamic art the infinite pattern, the arabesque, and stylized calligraphy all have significant symbolic functions wherever they occur; each in its own way is a surrogate in the physical world of such spiritual

> concepts as Allāh's infinity, transcendence, and unity. . . .
>
> There can be no doubt that the arabesque is a fundamental religious symbol. . . . In all cases of the infinite pattern—which has no beginning or end and is self-contained—the design is at once symbolic both of Allāh's infinity and unity in multiplicity and at once expressive both of His transcendence and the concept of *al-tawḥīd*.[85]

Whatever conclusions they reach, studies emphasizing the religiospiritual and cosmological dimension of Islamic art are characterized by sweeping generalizations unsubstantiated by concrete data. The wide margin of difference in their symbolic interpretations of the arabesque indicates that a priori connections with mystical and theological doctrines need to be demonstrated with respect to specific historical contexts. The ahistorical and essentialist discourse on Islamic art reached a particularly broad public forum during the World of Islam festival in 1976, organized by various institutions and governments from both the Islamic world and the West to celebrate the 1400th anniversary of Muslim culture. The festival recycled many of the stereotypes that had originated in the nineteenth-century Orientalist discourse, but this time the intent was to provide concepts easily accessible to non-Muslim and Muslim audiences alike. Held all over Britain, but mostly centered in London, it featured an exhibition, *The Arts of Islam*, at the Hayward Gallery, accompanied by a series of related exhibitions, films, and publications. The publications, all of which appeared in 1976, included the exhibition catalog *The Arts of Islam* (featuring an introductory essay by Titus Burckhardt), Burckhardt's *Art of Islam: Language and Meaning*, Nasr's *Islamic Science*, and Issam el-Said and Ayşe Parman's *Geometric Concepts in Islamic Art*.

As Grabar noted in his critical review of the festival, the objects in the *Arts of Islam* exhibition were not grouped according to the usual chronological, regional, iconographic, and stylistic criteria but were presented in terms of such ahistorical categories as calligraphy, geometry, and vegetal ornament, "characteristics or attributes which are alleged to be particular to the artistic creativity of the Muslim world, which make Islamic art different from other arts, and therefore justify an idiosyncratic presentation."[86] Grabar interprets the ideological message of the festival, characterized by its marked "reluctance to deal with history," as follows:

> The message was that of the basic unity of Islamic art and by extension of Islamic civilization in the past and, ideally, of most Muslims today. By a fascinating sleight of hand, the profoundly Islamic theological notion of *tawhid*, of the absolute oneness of God, was transferred not only to the community, the *ummah*, but also to the objects and buildings sponsored and used by the community of Muslims. To the single message of a unique Divine Revelation there corresponds a visually perceptible artistic creativity of comparable unity. And then the identification of the principles which create that unity acquire automatically a culturally normative value.[87]

These normative values reduced the rich complexity and multiplicity of Islamic visual culture(s) into simple prescriptive formulas meant to guide contemporary architectural projects in the Middle East. It is no surprise, then, that Burckhardt's catalog introduction identified architecture, represented in the exhibition with color projections, as the main focus of Islamic creativity to which the decorative arts were subordinated, a leitmotif in many nineteenth-century publications on ornament.[88]

Burckhardt once again attributed the unity of Islamic art, based on a "common language," to the pivotal concept of *tawḥīd*, accompanied by the mystical search for cosmic unity, and the spiritual ethos of a culture permeated with the Muslim revelation.[89] Nasr's introduction to *Art of Islam* rejected the Western interpretation of Islamic art as "decorative" and praised Burckhardt's ability to penetrate its "essence" by speaking "from within the Sufi tradition of the profoundest aspect of wisdom with an authority which can only come from actual experience and realization of the world of the spirit." He added:

> Islamic art is at last revealed to be what it really is, namely the earthly crystalliza-

> tion of the spirit of the Islamic revelation as well as a reflection of the heavenly realities on earth, a reflection with the help of which the Muslim makes his journey through the terrestrial environment and beyond to the Divine Presence Itself, to the Reality which is the Origin and End of this art.[90]

Burckhardt's book, dominated by decontextualized illustrations of abstract ornament in various techniques, revived such Orientalist stereotypes as the nomad who had "little feeling for the conventions of architecture" but instead valued geometric ornaments derived from the woven textiles of tents, together with the ethnoracial categories of "the Arab," "the Turk," and "the Persian" that represented "vastly different mental types." Nevertheless, differences were unified by the ubiquity of the sacred book since "the entire life of a Muslim is filled with Quranic formulae, prayers, litanies and invocations in Arabic."[91] Burckhardt assigned a central role to the arabesque, another favorite Orientalist theme revived with the English translation of Kühnel's *Die Arabeske* (translated by Ettinghausen in 1976). Unlike Kühnel, who focused exclusively on the vegetal arabesque, however, Burckhardt treated all of its variants with particular emphasis on the "spirit of geometry":

> For a Muslim artist or—what comes to be the same thing—a craftsman who has to decorate a surface, geometrical interlacement doubtless represents the most intellectually satisfying form, for it is an extremely direct expression of the idea of Divine Unity underlying the inexhaustible variety of the world.[92]

The special role of geometry as a metaphor for divine unity was also stressed in other publications associated with the festival. In his book *Islamic Science,* for instance, Nasr claimed that the Muslim "love for mathematics, especially geometry and number, is directly connected to the essence of the Islamic message, which is the doctrine of Unity (*al-tawḥīd*)."[93] He added, "Nowhere is the sacred character of mathematics in the Islamic world view more evident than in art, where with the help of geometry and arithmetic matter is ennobled and a sacred ambiance created wherein is directly reflected the ubiquitous Presence of the One and many."[94]

Another monograph devoted to the subject of geometry was El-Said and Parman's *Geometric Concepts in Islamic Art,* whose foreword by Burckhardt once again linked the sacred geometry of Islamic art with the concept of *tawḥīd:*

> At the basis of this geometry there lies the circle which is an image of an infinite whole and which, when it is evenly divided, gives rise to regularly shaped polygons which can, in their turn, be developed into star-shaped polygons elaborated indefinitely in perfectly harmonious proportions. . . . In the Islamic perspective, this method of deriving all the vital proportions of a building from the harmonious division of a circle is no more than a symbolic way of expressing Tawhid, which is the metaphysical doctrine of Divine Unity as the source and culmination of all diversity. It is not surprising, therefore, that Muslim artists should have explored all the geometric systems that depend upon the regular division of the circle.[95]

El-Said and Parman's text, which attempted to decipher the geometric formulas used in constructing surface patterns, neither showed an awareness of surviving scrolls (published by Soviet scholars and Christie) nor of practical geometry manuals (studied by Franz Woepcke and cited by such authors as Prisse d'Avennes and Gayet): "To our knowledge, no record has survived to instruct us in the theory of designing Islamic geometric patterns."[96] The authors analyzed a wide variety of two-dimensional geometric patterns generated by underlying grid systems dominated by the circle, with its radius constituting the basic unit of measure. They compared the repetition of modular units in visual patterns to music, poetry, and calligraphy, a comparison commonly made in nineteenth-century Orientalist writings and in ornament studies.

Testifying to the sudden popularity of this topic, in the same year, 1976, two other books were published on the geometric arabesque, Keith Critchlow's *Islamic Patterns: An Analytical and Cosmological Approach,* featuring an introduction

by Nasr,[97] and David Wade's *Pattern in Islamic Art*.[98] Characterized by short texts that briefly touched on the a priori religious, mystical, and cosmological meanings of two-dimensional geometric designs, these works essentially were pattern books providing guidelines for contemporary architects practicing in the Middle East. In that respect they recall nineteenth- and early twentieth-century European publications on ornament that left out three-dimensional patterns, such as Bourgoin's *Arabic Geometrical Pattern and Design*, which had been reprinted without its text for the same market in 1973. Their main difference from earlier publications on the same subject was an insistence on the Islamic symbolism of abstract patterns, no longer presented as merely decorative motifs. Nasr's foreword to Critchlow's book praised it as the first study by a non-Muslim author to explore the misunderstood tradition of Islamic art, usually regarded as no more than decoration. Critchlow, a teacher at the Architectural Association School of Architecture and the Royal College of Art in England, had been invited in the early 1970s to become an associate of the Imperial Iranian Academy of Philosophy in Tehran by its director, Nasr, and was chosen as a design consultant for a new mosque in that city. It was in those years that he prepared his book on Islamic geometric patterns. It is therefore not surprising that his writing contained unmistakable echoes of Burckhardt's and Nasr's works on Islamic mysticism and cosmology.[99]

To summarize, then, the symbolic interpretation of Islamic geometric patterns can be traced to a common intellectual milieu. Its recurrent ingredients were an emphasis on architecture to which the decorative arts were subordinated, a romantic Sufi universalism (with particular attention to Maghribi and Iranian mysticism), the assumption of an inner esoteric dimension of outer artistic forms, the stress on the doctrine of *tawḥīd* with its cosmological corollary of "unity in multiplicity," and the total rejection of historical context. The publications coordinated with the World of Islam festival, which as Grabar noted "still form the most coherent statement about Islamic art available to students or to the general public,"[100] attributed universalizing symbolic meanings to geometric patterns without any demonstration of the presumed link with mystical and religious doctrines in particular historical settings. Therefore, the still-popular conclusions of these methodologically unrigorous publications, which occasionally do contain perceptive insights, need to be tested by carefully framed nuanced contextual studies.

Gombrich was one of the first to criticize the methodologically problematic approach publicized by the *Arts of Islam* exhibition. In *The Sense of Order* he disputed this exhibition's basic assumptions:

> The visitor must be reassured that there is more to the arabesque than meets the eye. The revelation of symbolic meaning resembles an initiation into the deeper mysteries of the tradition. It is clear . . . that there is no concrete evidence for these interpretations. Certainly a contemplation of ordered systems could have "religious symbolic connotations." Whether these connotations would fit in perfectly with the tenets of Islam is a different matter. . . . Here the search for meaning coalesces with the tendency . . . of looking for some principle of unity among all manifestations of a culture or period. Being characteristic of Arabic decoration the arabesque must also partake of the essence of "Islamic thought.". . . In linguistics the quest for the "spirit" of a language has been abandoned and so has the search for the original meaning of roots as a guide to semantics. Instead interest has begun to centre on the synchronic analysis of how a language actually functions in any one community. The student of design would do well to follow suit.[101]

Stuart Durant's *Ornament: 1830–1980*, 1986, similarly criticized the festival's publications as being "all too inclined to attribute mystical significance to Islamic decoration."[102]

In his Mellon Lectures of 1989, published as *The Mediation of Ornament*, 1992, Grabar also rejected the symbolic interpretation of geometric patterns:

> Many arguments of logic and of fact exist against this immediate interpretation of geometry, however appealing it is to a curious mixture of Western orientalists and Islamic fundamentalists. The most

> important objections are several. There does not exist, to my knowledge, a single instance justifying the views that the Muslim community, the *ummah,* as opposed to individual thinkers, understood mathematical forms as symbolizing or illustrating a Muslim cosmology.[103]

In an attempt to reassert the universal values of Islamic geometric design, Grabar proposed that geometry, like calligraphy and vegetal ornament, functions as a "perfect intermediary, for it attracts not to itself but to other places or to functions other than itself." He concluded that "geometry is a passage, at best a magnet, to something else that it does not identify but which the culture deems desirable."[104] As an "object of emotional or psychic involvement" that gave the viewer a remarkable freedom of interpretation, geometry was devoid of cultural specificity:

> Geometry really works only as an intermediary. As an intermediary, it leaves the viewer or user a freedom of choice no other intermediary seems to offer. In this respect, as a harbinger of free choice, geometry is a most dangerous mediator. . . . The penalty of freedom in the arts is loss of meaning. Its reward is accessibility to all. Humble triangles on a dress or in the weaving of a basket or the very sophisticated brick walls of Iranian towers share an ability to make us wonder what they mean, because, like moths or butterflies, we are attracted to an abstraction which seems to be devoid of cultural specificity. It is only meant to be beautiful."[105]

Like Gombrich's psychology of decorative art, Grabar's book highlighted the universal psychological factors at work in the perception of abstract patterns that mediate sensual pleasure. Both authors viewed such patterns as primarily decorative, a view rejected by writers who attempt to charge the same patterns with a priori symbolic meanings. Grabar's theory of intermediaries aimed to bridge the "boundaries between ornament and reality" through a psychological framework of perception within which the viewer and the abstract image subjectively interact. He deemphasized culturally significant contextual factors, being interested in private perceptions of a universal kind. By definition such a universalizing Gombrichian psychology of perception does not concern itself with culturally constructed codes of recognition and sign systems at work in the process of visual communication. Grabar expressed doubt "whether it is appropriate to seek a philosophical explanation or even parallel for the arts of medieval and premodern times in the Islamic world," since he found it unlikely that philosophy, literary theory, theology, or mysticism informed the sphere of visual aesthetics. This freed the field of Islamic art from the monopoly of specialists to a much wider audience, giving the art historian the "uniquely interesting task . . . of devising the appropriate contexts, historical or contemporary, within which Islamic art should be understood."[106]

Grabar's psychological theory of intermediaries, which privileged the category of sensual pleasure, and other theories that continue to interpret abstract patterns as religiospiritual symbols perpetuate the "decorative versus iconographic" polemic that has polarized the study of Islamic visual culture since the nineteenth century.[107] This binary opposition, grounded in the construction of a sharp dichotomy between abstract patternmaking and mimetic representation in the Western tradition of art, has deeply colored the literature on the "character" of Islamic art.[108] The ongoing ideological split in the secondary literature can only be mediated by a paradigm shift capable of transcending the culture-bound opposition between iconographic representation and ornamental patternmaking. A semiotic framework can be particularly useful in addressing the problematic issue of cultural specificity and meaning in a visual tradition that employed repetitive abstract signs whose signifying potential was largely contextual. Such a framework can help dissolve the sharp dichotomy between the "iconographic" and the "decorative" by investing abstract patterns with a wide range of culturally relevant associations—even contradictory ones—depending on specific settings. Before exploring the semiotic dimensions of Islamic abstract patterns as context-bound sign systems open to a plurality of multilayered meanings, however, it is necessary to analyze the *girih* mode as a historically circumscribed phenomenon bound by identifiable regional and chronological parameters.

NOTES TO PART 2

1. Johann Wolfgang von Goethe, "Hafis Nameh," in *The Poems of Goethe,* trans. E. A. Bowring (New York: Gordon Press, 1974), 892.

2. The German Benedictine monk Theophilus, who was a practicing craftsman himself, included in his twelfth-century technical manual *De diversis artibus* a section on metalwork explaining "whatever Arabia adorns with repoussé or cast work, or engravings in relief"; see Theophilus 1986, 4. During the Renaissance arabesques were used in Venetian-Saracenic metalwork, and they appeared in pattern books published from the early sixteenth century onward, such as those of Francesco di Pellegrino, Jean Gourmont, and Balthasar Sylvius; see Gombrich 1979, 85–86; and Ward-Jackson 1967.

3. For the nineteenth-century literature on ornament and its vast bibliography, see Durant 1986. Many of the works cited below are discussed in Durant's richly illustrated and useful book. See also Gombrich 1979; Kroll 1987; Darby 1983; Brett 1992; Creswell 1961; and idem 1973.

4. See Lewis 1835; Roberts 1837; idem 1842–1849; Walsh 1838; Daniell 1795–1807; and Hodges 1786. This illustrated travel literature is analyzed in Bozdoğan 1988; and Darby 1983.

5. Coste 1975. For the involvement of colonial powers in studying and preserving the architectural heritage of Arab lands, see Reid 1992; and Mitchell 1988.

6. Prisse d'Avennes 1983, 22–23.

7. Gayet 1893, 310, 304–5. See idem, 57: "By proscribing the human form, the *hadith* summed up into a dogma the inclination of spiritualist races; by renouncing it, Arab art yielded to a hereditary repugnance whose trace reappears at each step in the history of the people of the Orient."

8. According to Gayet the abstract forms of Arab art reflected a mystical sensibility. See Gayet 1893, 180: "Each polygon, each arabesque, each inscription . . . extends itself into that softly resigned mysticism that at all times has constituted the battleground of Oriental belief."

9. Gayet 1893, 307. See also idem 1978, where Gayet argued that the ecstatic mystical reveries of Arab art were not so characteristic of the "*génie des races de l'Iran*" (genius of the races of Iran); Persian Islamic art was less spiritual and more prone to figural representation, which the Shiʿi "schismatics" tolerated.

10. For the development of the concept of the arabesque in Germany, see Kroll 1987.

11. For various definitions of the arabesque, see Riegl 1893 (1992); Herzfeld 1987; Kühnel 1960; and idem 1977.

12. Goury and Jones 1842–1845, commentary on pl. 1.

13. See Gayet 1893, 310: "And isn't polygonality the tracing of the rich and primitive textiles of the tent, which the Arab, still wandering and semisavage, used while camping in the desert?"

14. In nineteenth-century publications on Islamic architecture, linear drawings tended to flatten facades and architectonic elements, stripping away their spatial qualities to translate them into decorative patterns that could be recycled at will. Bozdoğan has observed that the architectural drawings of these books reduced light, shadow, texture, and depth to an interplay of linear patterns: "The color and corporeality of the dome of Mescid-i Shah in Isfahan, for instance, eludes the 1842 survey drawing of Charles Texier no matter how complete and accurate the latter is rendered. . . . Nor is it possible to capture in a two-dimensional drawing, as in Owen Jones' pattern book, the precise quality of ornament inside the dome of a mosque when the drawing by its nature strips away the essential spatiality of this ornament"; see Bozdoğan 1988, 41. For the Orientalist image as "object of consumption," see idem, 43–45.

15. For another early encyclopedia of ornament, see Wornum 1856, which discussed Egyptian, Greek, Roman, Byzantine, Saracenic, Gothic, and modern styles from the Renaissance onward. Wornum opposed excessive naturalism in ornament, which like music had to be based on such abstract principles as repetition, measure, rhythm, and harmony. Friedrich Maximilian Hessemer's work *Arabische und alt-Italienische Bau-Verzierungen,* 1842, resembled pattern books with its chromolithographic plates of ornaments derived from the monuments of Cairo, Alexandria, and Italy.

16. Brett 1992, 90. The second edition of Jones's influential book was published in 1868 and translated into German and French.

17. Jones 1982, 8.

18. Ibid., 66, 5.

19. Ibid., 74.

20. Cited in Durant 1986, 89. For Jones's wallpaper and textile patterns generated by geometric grids like those of the Alhambra, see Darby 1983, 90.

21. Jones 1982, 56–59.

22. Riegl 1893, see esp. pp. 267, 302–3, 308, 311–15, 326. See also the annotated English translation of *Stilfragen,* Riegl 1893 (1992), esp. pp. 229–305. For the turning point in the tenth and eleventh centuries, see Allen 1988, 15, 54–56; and part 3, chapter 6, of the present volume.

23. Riegl often cited the works of Jones, Bourgoin, Gayet, Prisse d'Avennes, and Gottfried Semper, whose *Der Stil in den technischen und tektonischen Künsten,* 1860–1863, emphasized the need to learn the basic principles of decoration from non-Western ornamental traditions. For other Austrian theorists of ornament, see Kroll 1987, 47–68.

24. Bourgoin 1873a, 4. It has been suggested that Bourgoin was interested in the grouping of plant cells and may have used this information to understand tessellation; see Durant 1986, 65.

25. Among the early works that treat the muqarnas are Goury and Jones 1842–1845; and Gayet 1893.

26. See Bourgoin 1873a, 1–2, where he noted "a considerable difference between the Moresque art of Spain and the Arab art of Egypt and of Syria." He speculated that a similar difference must have existed "in other regions of the vast Muslim empire."

27. Ibid., 3.

28. Bourgoin 1879, 5–11. Bourgoin identified three periods of Arab art: the formative period (*l'époque Byzantine,* up to the twelfth century), the definitive period (*l'époque arabe,* from the twelfth to the fifteenth century), and the period of decadence (*l'époque moderne,* from the fifteenth century to the present). The same biological metaphor of growth and decline, so widely used by nineteenth-century European historians of art and architecture, also appears in Prisse d'Avennes's *L'art arabe,* where its political implications are transparent; see Prisse d'Avennes 1983. In the author's words, the book traces the "formation, flowering, and decay of Muslim civilization in Cairo" up to the arrival of the French armies who rescued the Arabs from Ottoman rule, "an epoch during which artistic inspiration was all but extinguished under the Turkish yoke" and whose few architectural works of merit reflected "the supreme protest of Arab genius against barbarism." This view, constructed to legitimize French colonial rule in Egypt, would be perpetuated within the framework of Arab nationalism that readily appropriated the racially defined notion of "Arab genius." Such Orientalists as Prisse d'Avennes saw the "Arab genius" as the "pure source" of Islamic visual culture whose stylistic and regional variants were merely a function of climate and racial character.

29. The Orientalist discourse accentuated the unbridgeable distance between two separate worlds and time frames; it not only implied the superiority of the West but also rationalized the role of Europe as a catalyst for change in the colonized Arab lands; see Said 1979; Bozdoğan 1988; Mitchell 1988; and Çelik 1992.

30. Bourgoin 1873a, 24, 4.

31. Ibid., intro.

32. Ibid., intro.

33. Bourgoin described the geometric character of Arab art as follows: "Elegance and complexity by geometric involutions more or less distinct or mixed, and constructed with symmetry. Abstract figures, linear inflections, and a sort of organic growth: in other words, purely geometric themes that are graphically translated

by working drawings, and technically executed by being transferred onto materials, such is the essential basis of Arab art." While Greek art was inspired by the animal realm and exhibited beauty and clarity through representational plastic forms arranged with attention to order, rhythm, and measure, Far Eastern art reflected the vegetal realm, imbued with the spontaneous vivacity of curvilinear floral motifs that defied order and symmetry; see Bourgoin 1879, 5–11.

34. Bourgoin 1873a, 3–4.

35. See ibid., 3: "Moresque architecture is an architecture of decoration, it is this that makes it inferior, and that is why one cannot judge the art of the Orient by what one knows about Moresque or African countries."

36. Viollet-le-Duc 1875, 457–58.

37. Bourgoin 1873a, intro.

38. Parvillée 1874, 11–12. For Edmond Duthoit, see Barry Bergdoll, "'The Synthesis of All I Have Seen': The Architecture of Edmond Duthoit (1834–89)," in Robin Middleton, ed., *The Beaux-Arts and Nineteenth-Century French Architecture* (Cambridge, Mass.: MIT Press, 1982), 216–49.

39. Prisse d'Avennes 1983, 186.

40. Bourgoin 1873a, intro.

41. Bourgoin wrote that monumental architecture "particularly holds under its dependence the arts and crafts which are directly linked to it"; see Bourgoin 1873b, ii.

42. Ibid., 48, 209–11.

43. See ibid., 33: "These ideas of measure and scale tend to regularize the expansion or [compositional] development of forms and of ornaments; this is necessary in itself and for the detail. Morover, in order to have concordance in the general chord, it is necessary that a measure, a eurythmy, and a general metrics harmonize each of the constituent series, subordinating one to the other, and as a whole to the overall harmony."

44. Cited in Washburn and Crowe 1988, 8–9.

45. Cited in ibid., 8–9.

46. Cited in ibid., 8–9.

47. See also Prieto y Vives 1907; idem 1932; and idem 1932–1935.

48. See Gaganov 1958, 183; and Baklanov 1947, 102–11. Meyer and Hamlin are cited in Washburn and Crowe 1988, 7.

49. For studies on ornament, see Rempel' 1961; Denike 1939; and Yuldashev 1957. Such studies not only were applicable to modern architecture but also helped to forge regional identities in the modern Soviet republics. Self-contained diachronic studies on the architectural ornament of various republics from pre-Islamic times up to the modern era reinforced artificial national boundaries and concealed a striking reluctance to engage in contextual interpretations that stressed religious culture. The practical working methods of medieval builders and the universal language of the geometric and mathematical formulas they used conveniently neutralized the historical, ideological, and cultural contexts of monuments built under Muslim rule. The textbook by Muradov, Zasypkin, and Lukasheva is mentioned in Bulatov 1988, 264–65.

50. Although Müller has been credited with having found at the Alhambra all of the seventeen symmetry groups possible in one-color plane patterns (known as plane crystallographic groups), it was not until 1987 that Spanish mathematicians and topologists were able to document their presence; see Washburn and Crowe 1988, 5, 20. Finite patterns have a central point axis around which elements can rotate or through which mirror axes can pass (other symmetries, such as translation or glide reflection, are not possible in this category). One- and two-dimensional patterns with a single color have respectively seven and seventeen different motion classes, consisting of combinations of the four basic motions possible in the Euclidean plane (reflection, translation, rotation, glide reflection). To these seven strip groups and seventeen plane groups can be added 230 three-dimensional crystallographic groups. Crystallographers also systematically have explored the greatly increased number of variants possible with the addition of two or more colors (dichromatic and polychromatic) to these symmetry groups. For more information, see Weyl 1952; followed by Shubnikov and Koptsik 1974, which summarized the work of Soviet crystallographers. Until recently the most extensive study of two-color patterns had been attempted by the Soviet school of crystallography, made available in English by Shubnikov et al. 1964. The nearly infinite variety of patterns with more than two colors has been explored in Loeb 1971; Wieting 1982; and recently in Grünbaum and Shephard 1987, which is regarded as the definitive text for the mathematical theory of patterns.

51. For one example, see Washburn and Crowe 1988, ix, where the book's purpose is explained as follows: "In this book we demonstrate how to use the geometric principles of crystallography to develop a descriptive classification of patterned design. Just as specific chemical assays permit objective analysis and comparison of objects, so too the description of designs by their geometric symmetries makes possible a systematic study of their function and meaning within cultural contexts . . . analysis classifies the underlying structure of decorated forms; that is, the way the parts (elements, motifs, design units) are arranged in the whole design by geometrical symmetries which repeat them. . . . We have attempted to offer a more comprehensive survey of patterns occurring on decorated objects from cultures all over the world and systematically show how to classify the finite, one-dimensional, and two-dimensional one- and two-color designs with the use of flow charts and other detailed descriptions of symmetry motions and colors present." See also Hargittai 1986.

52. See Makovicky and Makovicky 1977, 58–68; Mamedov 1970; idem 1986; and Niman and Norman 1978, 489–91. Makovicky, Makovicky, and Mamedov applied crystallographic analysis to the study of Islamic geometric patterns and showed how such abstract designs are useful as tools for teaching two-dimensional and color symmetry. Noting that the drawings of Escher (who acknowledged being influenced by the Alhambra) have already become crystallographic classics, Makovicky and Makovicky identified Islamic geometric patterns as a "treasury for crystallographic teaching" for which they also recommended the less complicated Roman, Byzantine, and Romanesque mosaics and Gothic vaulting patterns. They also pointed out the usefulness of Bourgoin 1879 for this purpose. Niman and Norman 1978 was part of a project initiated in 1976 by the Metropolitan Museum of Art and Hunter College on the teaching of secondary-school mathematics through works of art, a project whose first part drew exclusively on Islamic geometric patterns. The authors encouraged other American math teachers to use Islamic designs whose "abstractness, inherent logic, and universality" made them "a particularly valuable means of teaching topics such as tessellation, algebra and symmetry."

53. Chorbachi 1989, 757, 774. As an artist Chorbachi has experimented with developing new geometric designs inspired by traditional patterns: "I have tried, visually, to show here that returning to the study of medieval Islamic tradition does not necessarily mean to advocate a move from the present century backwards to medieval times. . . . Rather, the opposite may be the case, for Islamic tradition is so strong that, if we are in touch with the language of the present time and ground ourselves in this strong old tradition, we can arrive at an expression that is not only contemporary but that could be meaningful and valid in the coming century"; see idem, 788.

54. This book is not a study of the symmetrical properties of the Topkapı scroll's patterns—it is mainly concerned with the cultural and historical contexts in which they were created, together with their implications for aesthetic theory. Mathematical analysis of the symmetry groups to which these patterns belong is a task for which I am not qualified, but it is a task that I hope others will undertake in the future. Chorbachi, who made a pioneering effort to apply the scientific language of

group theory and crystallography to the study of Islamic geometric patterns, was also among the first few scholars to turn to primary sources of scientific manuscripts on practical geometry written specifically for artisans. She wrote: "It is essential to study in detail the scientific manuscripts and old documents that are now available to us, for they bring us closest to the true historical procedure of the Islamic science of design"; see Chorbachi 1989, 776. As such, she moved beyond symmetry issues to the step-by-step process of design in the medieval era. For these manuscripts, see Bulatov 1988; and part 4 of the present volume.

55. See Bozdoğan 1988, 44: "A contemporary version of what Said calls 'Orientalizing the Orient' is, not surprisingly, enjoying growing appeal both for Western architects/firms competing for corporate jobs in the non-Western world and for the architects of the non-Western world in their post-traditional, post-colonial—and frequently post-Modern—search for national/cultural identity."

56. Herzfeld 1987, 365.

57. Ibid., 364–67.

58. Dimand 1930, 12; Ettinghausen 1944; idem 1979. See also Sourdel-Thomine 1965, which repeated the stereotyped interpretation of Islamic art as an essentially decorative tradition: "It is justifiable to define Islamic art as a whole as an art of decorators and ornamenters, concerned to decorate every surface with a multiplicity of figures springing from their own imagination in accordance with a repertoire of motifs. . . . This art of the ornamenters thus corresponded to a peculiar regard for agreements and harmonies, founded, not without some aridity, on the observation of rules such as the horror of the void and the continuation of the line, in a climate which produced also the melodic line of Arab music and the cadences of its poetry." The author identified the arabesque "among the most typical aspects of the art of Islamic countries."

59. Herzfeld 1987, 367.

60. Kühnel 1960.

61. Kühnel 1977, 8–9.

62. Ibid., 5.

63. Ibid., 6. This statement ignores the fact that not all artisans practicing in the Islamic world were Muslims.

64. See Massignon 1921, 50–51: "Muslim art derives from a theory of the universe. . . . This theory is that, in the world, there is no form in itself, and there is no figure in itself, God alone being permanent." He added, "Just as in the scientific point of view that for them [Muslims] nature does not exist, but is simply an arbitrary series of accidents and atoms with no duration, so too in art we see that the negation of the permanence of the figure and of the form is precisely the principle." For a recent elaboration of this theory, see Tabbaa 1985. Ettinghausen 1944, which explained various tendencies of Islamic art by reference to Islam's essential characteristics, was criticized in Aga-Oglu 1954.

65. Grabar 1987, 178–94.

66. See al-Faruqi 1970a; idem 1970b; idem 1973; and idem 1989. Terry Allen, by contrast, disagreed with the view that the arabesque expressed "the secret inner workings of some 'Islamic mind'" and went as far as asserting that "there is nothing 'Islamic' about Islamic art"; see Allen 1988, 15.

67. al-Faruqi 1970b, 78–79.

68. al-Faruqi 1989, 261–69. For a further elaboration of the same themes, see al-Faruqi 1985.

69. Gayet described Arab artisans as follows: "They are first of all spiritualists; they see with the soul, whereas their so admired rivals of the imitative school see with their eyes and never the beyond"; see Gayet 1893, 181. See also Probst-Biraben 1907, 17–23. More recently Bürgel has also interpreted the arabesque in mystical terms, as a visual expression of joy and ecstasy. Moreover, he has associated the arabesque with magic: "Magical or quasi magical influences are ascribed to these three arts (poetry, music, painting) in countless cases related in sources from premodern Islam. Does not the idea suggest itself of interpreting the patterns of harmony and symmetry, of mirrorlike repetitions of motifs in chains or clusters or arabesques, as something closely related to the 'sympathetic' chains, the talismans of the magician?"; see Bürgel 1988, 22.

70. Probst-Biraben 1907, 20.

71. Ardalan and Bakhtiar 1973, ix–xii.

72. Ibid., xi–xiv.

73. Ibid., 21–27.

74. Ibid., 40.

75. Ibid., 3, 6.

76. Ibid., 129.

77. For additional biographical and bibliographical details, see Burckhardt 1987, 3–9.

78. Reprinted in ibid., 219–30.

79. Ibid., 227.

80. Ibid., 220.

81. Ibid., 217.

82. Ibid., 230.

83. Nasr 1987, 13.

84. Madden 1976.

85. Ibid.

86. Grabar 1988a, 147–48.

87. Ibid., 150.

88. Burckhardt observed that Islamic art was primarily aimed at creating a spiritual ambience that would encourage contemplation; this is why architecture played a central role, with the traditional crafts and calligraphy subordinated to its needs; see Burckhardt 1976b, 27; idem 1987, 228; and idem 1976a, 29.

89. See Burckhardt 1976b, 32: "The Muslim is not fascinated by the drama of individual artistic creation; rather his soul vibrates through the idea of the unity and immensity of God which are reflected in the cosmic order and also in the artefacts shaped by the hand of man."

90. Burckhardt 1976a, xv–xvi. See idem, 46: "But the most profound link between Islamic art and the Quran is of another kind: it lies not in the form of the Quran but in its *ḥaqīqah,* its formless essence, and more particularly in the notion of *tawḥīd,* unity or union, with its contemplative implications; Islamic art—by which we mean the entirety of plastic arts in Islam—is essentially the projection into the visual order of certain aspects or dimensions of Divine Unity."

91. Ibid., 45. According to Burckhardt, diversity was created by different "ethnic environments" that exemplified "the phenomenon of diversity in unity, or of unity in diversity"; see idem, 117.

92. Ibid., 63.

93. Nasr 1976, 75.

94. Ibid., 78.

95. El-Said and Parman 1976, ix–x.

96. Ibid., 7. The lack of awareness of surviving scrolls in this study is particularly surprising given that the Mirza Akbar scrolls were displayed in one of the exhibits coordinated with the World of Islam festival. For the catalog of that exhibition, entitled *Science and Technology in Islam,* see Harrow and Wilson 1976.

97. Nasr praised the works of Burckhardt and Schuon and reiterated the notion of spiritual concepts reflected in Islamic art: "Islamic spirituality could not but develop a sacred art in conformity with its own revealed form as well as with its essence. The doctrine of unity which is central to the Islamic revelation combined with the nomadic spirituality which Islam made its own brought into being an aniconic art wherein the spiritual world was reflected in the sensible world not through various iconic forms but through geometry and rhythm, through arabesques and calligraphy which reflect directly the worlds above and ultimately the supernal sun of Divine Unity." He stated that the Pythagorean-Platonic tradition was the origin of using numbers and geometric figures as keys to the structure of the cosmos and as symbols of the archetypal world and wrote: "Thanks to the efforts of a small number of authorities, foremost among them F. Schoun and T. Burckhardt, Islamic art is gradually coming to be understood for what it is, namely a means of relating multiplicity to Unity by means of mathematical forms which are seen, not as mental abstractions, but as reflections of

the celestial archetypes within both the cosmos and the minds and souls of men"; see Critchlow 1976, 6.

98. Wade believed the Islamic ethos found its consummate artistic expression in the application of elaborate geometricism to the infinite pattern. He wrote that geometric patterning based on scientific developments should be seen as "integral to the Islamic spirit": "Its widespread usage suggested that this mode of expression satisfies something essential in Islam. These patterns in their infinite form reflect the basic Islamic creed of the indivisibility of God. Endlessly repeating themselves in elaborate complexity these *mandalas* of Islam are a reflection of the One God whose influence is not 'centred' in a divine manifestation, as in Christianity, but whose presence is an even and pervasive force throughout His creation. . . . This art is also a science, but the distinction is irrelevant to Islam, where architecture and geometric ornament develop hand in hand with the advances made in mathematics"; see Wade 1976, 7. Wade also emphasized the Platonic and Pythagorean origin of Islamic geometric patterns; his brief introduction is followed by an analysis of the underlying grids of a large number of two-dimensional patterns.

99. Critchlow 1976, 6. Critchlow freely assigned cosmic meanings to Islamic geometric patterns. For example, the hexagon "is related archetypally to the six days of the Creation"; see idem, 156; and twelve "gives the number of hours in a full daily cycle, one half being dominated by the sun, the other by the moon"; see idem, 160. In addition eight-, sixteen-, and thirty-two-pointed stars "can be taken to be cosmically related on the one hand, to the four-fold division of the seasons etc., the eight-fold division relating to the orbital cycle of retrograde loops as seen in the orbit of Mars, and the subsequent divisions by multiples of the primary archetype of four and eight"; see idem, 161. For a recent elaboration of these cosmological interpretations, see Critchlow 1988.

100. Grabar 1988, 150.

101. Gombrich 1979, 225.

102. Durant 1986, 143. For a critique of mystical and cosmological interpretations of Islamic geometric patterns, see also Chorbachi 1989. After analyzing the fallacies of publications on this subject during the 1970s, Chorbachi observed: "The symbolic mystical interpretations that have proliferated in these books on Islamic geometric design, pattern and ornament are based on a modern understanding of Islamic literature. There is no documented evidence that such interpretations were given to the art forms when they were created hundreds of years ago"; see idem 1989, 760.

103. Oleg Grabar 1992, 151.

104. Ibid.

105. Ibid., 154.

106. Ibid., 233–34.

107. This polemic continues to divide recent studies on the arabesque, studies that tend to repeat earlier stereotypes. Among the works that see the arabesque as an essentially decorative element are Sourdel-Thomine 1965; and Sandler 1976. Allen was also reluctant to assign iconographic significance to the arabesque and to geometry, which he admitted probably conveyed some associations in at least some cases: "Whatever these may have been, the use of the arabesque and geometry always serves the purpose of increasing the visual richness of an object or building, and I believe this to be their primary purpose"; see Allen 1988, 54, 56. See also idem, 2: "Ironically the idea of the 'Islamicness' of Islamic art has been picked up by Muslims unaware of how deeply rooted it is in a highly culture-bound Western view of the 'East.'" Such authors as Nasr, Lois al-Faruqi, and Ismaʿil al-Faruqi continued to assign specifically Islamic meanings to the arabesque. The recent appearance in Iran of several practice-oriented publications on geometric patterns, with "how-to" instructions addressing professional architects charged with designing buildings appropriate for the new Islamic regime, once again reflects the perception of geometric patterns as symbolic stamps of cultural and religious identity in some Muslim circles; see Firishtah Nazhad 1977; Lur'zadeh 1979; Shiʿrbaf 1982–1983; and Buzurgmihri 1982.

108. This dichotomy informed Gombrich's different treatment of abstract patterns and representational art in two separate works; see Gombrich 1960; and idem 1979.

PART 3. THE GEOGRAPHICAL, CHRONOLOGICAL, AND SEMANTIC HORIZONS OF THE GEOMETRIC MODE

To underrate Baghdad is to underrate Rome.

—Ernst Herzfeld[1]

CHAPTER 6. GEOMETRIC PATTERNING BEFORE THE MONGOLS

The geographical and chronological parameters of the so-called geometric arabesque were not systematically explored in the secondary literature discussed in the previous section. Although nineteenth- and early twentieth-century publications on the subject often suffered from the limited amount of documentation available at that time, more recent ahistorical studies on the religiospiritual and cosmological symbolism of the arabesque willfully overlooked the accumulated body of information on the regional and chronological complexities of Islamic visual culture to underline a unified essence that transcended time and space.

As we have seen, the nineteenth-century literature on the subject concentrated on the more accessible monuments of Arab civilization in Syria, Egypt, North Africa, and Spain. That is why Riegl's exemplary analysis of the arabesque in *Stilfragen,* which frequently quotes the works of Jones, Gayet, Prisse d'Avennes, and Bourgoin, was limited to examples primarily selected from Arab monuments. Like Bourgoin, Riegl admitted the limitations of available information and postponed the study of regional variations beyond the Arab world to future generations whose task it would be to "investigate the distinctions within the geographically far-flung regions of Islamic culture and to establish the nature of the variation." Given his agenda to trace the genetic continuity of vegetal ornament from antiquity to the present, Riegl preferred to adopt an "all-encompassing perspective" rather than to "seek or establish distinctions."[2] He wrote:

> Surely further study of the history of Islamic art will eventually enable us to recognize and isolate the characteristics of individual local schools. Today we are still preoccupied with establishing the common denominator of the development as a whole, a development whose roots . . . went back to the common experience of late antique–Byzantine art, i.e., the art that dominated all of these regions across three continents when Islam first emerged.[3]

About two decades later Herzfeld and Friedrich Sarre's publications on the Samarra excavations opened up new horizons that firmly established the Iraqi Abbasid origin of the ornaments seen in the ninth-century mosque of Ibn Tulun at Cairo, previously viewed as a local Egyptian development of the arabesque that matured under Fatimid rule between the late tenth and twelfth centuries.[4] Arthur Upham Pope and Phyllis Ackerman's monumental *Survey of Persian Art from Prehistoric Times to the Present,* 1938–1939, also shifted the center of gravity in artistic innovation from Egypt and the Maghrib to the eastern Islamic lands. In his discussion of the "geometric style," whose post-eleventh-century development in the Iranian world he attributed to the arrival of the Seljuqs, Pope wrote: "West Islamic geometric ornament, so familiar to Europeans, has too often been accounted not merely the representative of style, but even its supreme expression. But compared with the best Iranian examples it betrays a certain meagerness (for all its intricacy) and artificiality." The complexity of multiple orders of superimposed geometric patterning seen in Iranian

architecture made the arabesques of the western Islamic world appear "relatively deficient in intellectual capacity and aesthetic judgment." Pope argued: "The best geometric ornament in Iran is different and superior. It is, in the first place, not the product of mere craftsmen, but, in the finer examples, is evidently the direct use of mathematical discipline."[5] Attributing the creation of geometric patterns to mathematically trained builders, he observed:

> The inventions of the Persian geometers are inexhaustible, but the principles are constant and all subject to definition in logical terms. For these patterns are the objective and visual records of laws embedded in the mind itself, logic expressed in linear relations, yet individualized by a penetrating aesthetic selectivity that endows them with beauty and emotion.[6]

New studies on the arts and architecture of Iran, Iraq, Anatolia, Central Asia, Afghanistan, and India provided a more balanced vision of the geographical and chronological variety within the vast Islamic domains. This contributed to a redefinition of the scope of the so-called arabesque, leading some scholars to place its origin in the ninth-century beveled style of Abbasid Samarra and others in the tenth- and eleventh-century eastern Islamic world from where it spread to the west between the twelfth and thirteenth centuries when it experienced its full flowering.[7] Nevertheless the information made available by new research and archaeological fieldwork did not result in a detailed analysis of the development of the arabesque and the mechanisms of its dissemination. In this section I will focus on the geometric mode, the main subject of the Topkapı scroll, outlining its spatial and temporal horizons together with its contextual associations as far as is possible given the serious gaps in the early Islamic archaeological record.

With its purely geometric vocabulary the *girih* was only one of many abstract modes of design that flourished in the medieval Islamic world in response to the constrictions placed on the scope of figural representation, which from the very beginning was excluded from religious monuments and illuminated Korans. Although figural representation had a rich life of its own throughout Islamic history, it was consistently relegated to profane contexts in architecture, the decorative arts, and miniature painting. This meant that nonfigural modes of representation that exclusively relied on a vocabulary of inanimate forms had to be formulated, forms that often found their way into nonreligious contexts as well. The intimate connection between inanimate designs and the religious contexts for which they were originally intended makes it likely that they would have been informed by the dominant theological orientations of the settings where they were created. These shifting orientations officially adopted to support differing claims of legitimacy in specific courts, which also happened to be the main centers of artistic production, no doubt colored the canonical visual idioms that stamped public religious monuments.

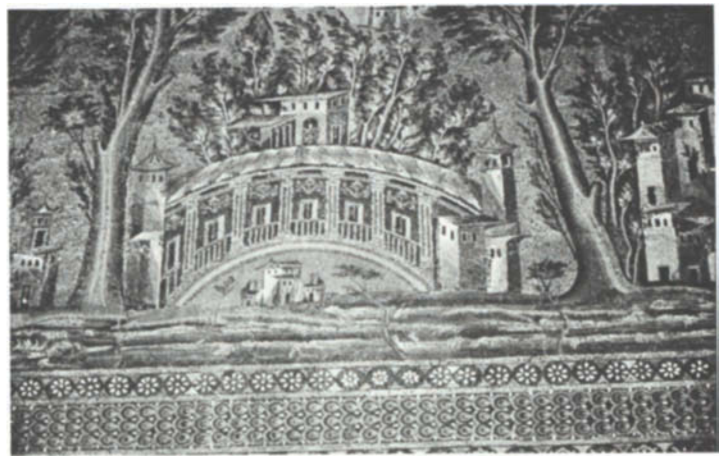
Even though there is no evidence in the primary sources to support the stereotyped notion that nonfigural visual idioms were considered the "essence" of the arts in Islamic lands, religious constraints did place an unprecedented emphasis on them. This should not, however, imply that the development of the so-called arabesque was an automatic one, given the availability of a wide range of nonfigural idioms not necessarily limited to an abstract vocabulary of geometric, vegetal, and calligraphic forms. It was only three to four centuries after the birth of the new religion that the abstract modes of design identified in Europe as the arabesque were favored, culminating by the late tenth and eleventh centuries in predominantly geometric schemes.

It is only natural to assume that the *girih*, a highly codified mode of geometric patterning with a distinctive repertoire of algebraically definable elements, was preferred for some reason over other forms of nonfigural design. The particular *kind* of geometry used lies at the heart of the problem. The *girih* mode, with its two- and three-dimensional formulations compiled in surviving examples of pattern scrolls, is characterized by its self-consciously limited vocabulary of familiar, almost emblematic, star-and-polygon compositions generated by invisible grid systems that eliminated a broad spectrum of alternative geometric

designs. What made it so appealing to the sensibilities of the medieval Islamic world and what were the circumstances of its invention?

The spotty archaeological record makes it difficult to pinpoint the *girih*'s time and place of origin and the processes of its dissemination. Interlaced geometric patterns, commonly used in window lattices, floor mosaics, and wooden ceilings during the Umayyad period (661–750), were hardly a prominent feature of early Islamic architectural decoration before the late tenth century. The nonfigural decorative vocabulary of Umayyad religious monuments was predominantly representational, with its Byzantinizing landscapes, architectural depictions, jeweled crowns, and identifiable fruits and trees (figs. 81–83). These elements were synthesized with Sasanian and pagan Arab motifs into a distinctive imperial Umayyad visual idiom whose geometric and vegetal patterns continued to exhibit a genetic link to Hellenistic, late antique, and Byzantine prototypes. This link was still apparent in the nonfigural decorative vocabulary of the early Abbasid period. Some examples from that period include the juxtaposed geometric and vegetal motifs of the marble mihrab and wooden minbar at the Great Mosque in Qairawan (believed to have been imported in the ninth century from Abbasid Baghdad) and contemporary carved wooden panels with similar motifs originating from Takrit in Iraq.[8]

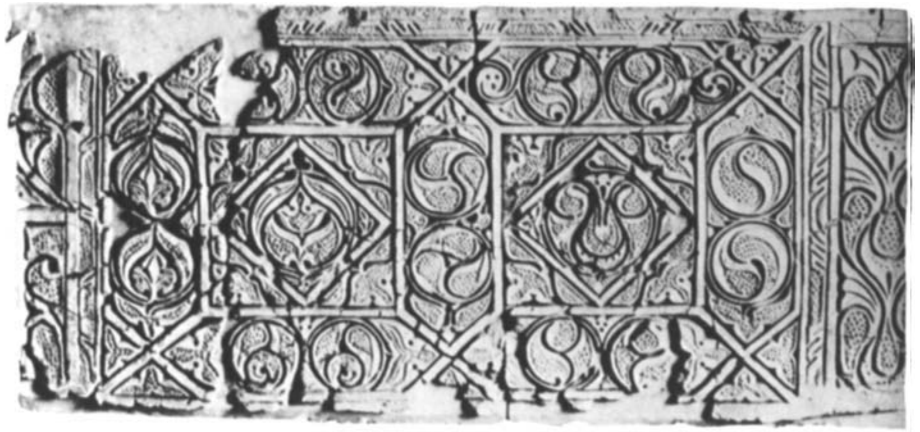
The transformation of classicizing vegetal and geometric patterns into the beveled style of the Abbasid capital Samarra (838–892) constituted a



81. Detail of mosaic panel depicting a river landscape with trees and buildings, from the west portico of the courtyard, Umayyad Great Mosque, Damascus, 705–715. Photo by author.

82. Detail of interior mosaics depicting jar, crown, and floral motifs, Dome of the Rock, Jerusalem, 692. Photo: Courtesy Eva Baer.

83. Detail of interior mosaics depicting vase, vegetal scroll, crown, and winged motifs, Dome of the Rock, Jerusalem, 692.



84. Dado, style A, Samarra, ninth century, stucco. Cairo, Museum of Islamic Art, I3849.

85. Panel, style B, Samarra, ninth century, stucco. Berlin, Staatliche Museen zu Berlin, Preußischer Kulturbesitz, Museum für Islamische Kunst. Photo: Copyright Bildarchiv Preußischer Kulturbesitz, Berlin.

86. Panel, style C, Samarra, ninth century, stucco. Berlin, Staatliche Museen zu Berlin, Preußischer Kulturbesitz, Museum für Islamische Kunst. Photo: Copyright Bildarchiv Preußischer Kulturbesitz, Berlin.

87. Panel with birdlike motif, Egypt, late ninth century, wood. Paris, Musée du Louvre, Département des Antiquités Orientales, inv. 6023.

radical innovation (figs. 84–87). The new visual idiom rapidly spread from the Abbasid capitals of Samarra and Baghdad to the caliphal provinces and to such semi-independent courts as that of the Tulunids (868–905) in Egypt. It deliberately abstracted vegetal and geometric designs derived from classical prototypes that had been assimilated by the Byzantine, Sasanian, and Umayyad imperial styles, transforming them into interpenetrating reciprocal shapes that dissolved traditional figure-ground relations. Its contiguous amorphous shapes, capable of continual metamorphosis into one another, recalled the intermediate state of primordial matter between formlessness and form. Ambiguous curvilinear patterns, with beveled edges creating undulating surfaces, sometimes featured geometric frames that compartmentalized elements distantly evoking vegetation and occasionally animate forms recalling birds.

The deliberate elusiveness of the beveled style, which resisted being resolved into intelligible forms with clearly delineated contours, seems to have reflected a concern with rupturing the classical ideal of mimesis. It has, in fact, been shown that its abstract patterns were direct translations or reinterpretations of classical prototypes, reflecting a programmatic process of abstraction whose rationale has so far escaped explanation. Unlike such scholars as Josef Strzygowski and Ernst Diez, who attempted to trace the Samarran beveled style to Turkic nomadic influences from Central Asia, Herzfeld and Ettinghausen linked it with some transitional Abbasid works, particularly two capitals discovered in Raqqa, one of which already displays an abstract treatment of shapes with beveled edges, while the other still preserves its Hellenistic form.[9]

It may not be a coincidence that this seemingly self-conscious change in visual representation came about at a time when the Abbasid court was intensely engaged in theological and philosophical debates about the unstable nature of matter in the physical world, related to such broader issues as God's absolute transcendence of matter and the status of the rational human soul as an incorporeal substance unconstrained by matter. These debates were triggered by the translation of Greek philosophical texts and culminated with the acceptance of Muᶜtazilism as an official doctrine by the Abbasid caliphs between 813 and 848, a doctrine that would continue to be influential in Baghdadi court circles under Buyid (945–1055) patronage until its adherents were systematically persecuted by the Great Seljuqs (1038–1194) who occupied Baghdad in 1055. Although establishing the possible correlation between Muᶜtazili sensibilities and the beveled aesthetic falls beyond the scope of my inquiry, it is nevertheless tempting to postulate that this official ideology informed the character of abstract visual idioms formulated at that time in the Abbasid court milieu.

The Muᶜtazila school affirmed the primacy of human reason and free will together with the absolute transcendence and oneness of God, who was completely beyond anthropomorphic attributes and the physical world. Anthropomorphic expressions used in the Koran with reference to God were, therefore, interpreted in a metaphorical sense by the adherents of the Muᶜtazila school who developed a new cosmology based on the dualism of essence (atom) and existence (accident). This atomistic view of matter, space, and time—conceived by Abu al-Hudhayl, who died in Samarra in the 840s, and elaborated by others—explained all phenomena in the physical world through the inherence of accidents in the atoms that composed matter. This was an ephemeral and perishable material world in perpetual flux where anything visible remained only accidentally bound to its apparent form.[10]

The vision of a continually fluctuating atomistic world open to endless permutation by incessant accidents may well have informed the Samarran beveled aesthetic with its deliberate ambiguity in representing natural forms, caught as if they were in an ambivalent zone between intelligibility and unintelligibility, being and becoming, actuality and potentiality. Was this peculiar mode of representation meant to be a visual commentary on the impermanence of matter as mere potentiality and as the unstable substratum of forms? Could the deceptiveness of visual perception implied by the willful obscurity of the beveled style have expressed the Muᶜtazili contempt for matter (liable to continually change form), thereby underlining the primacy of the rational human soul and of intellectual vision over seeing with one's eyes?

It is not unlikely that the Muᶜtazila theory of the atomistic universe could have engendered a

new way of representing the material world. If so, it was the merging of Greek philosophy with Muslim theology in a historically specific context—rather than a supposedly universal Islamic mentality—that may have inspired the Samarran beveled style, seen by many as the first example of the arabesque. Massignon did link the ephemeral character of Islamic art with the atomistic theory of the universe developed by Muslim theologians, but he failed to place his generalized comments in context and to distinguish between various competing atomistic theories. His reductionist correlation of a loosely defined theological worldview with an assumed unity of artistic expression thus helped perpetuate the problematic vision of a monolithic and ahistorical Islamic visual culture.[11]

The representational nonfigural vocabulary used in decorating the religious architecture of the Umayyads, who had sought to visualize the absolute power of God, his kingdom, and his throne by such concrete images as jeweled crowns and idyllic landscapes with heavenly mansions, must have implied an anthropomorphic vision that was vehemently rejected by the Muᶜtazila school.[12] The polemics of this school against anthropomorphism (*tashbīh*) completely divested God of eternal attributes (*taᶜṭīl*), an extreme position that was criticized by such orthodox scholars as Ahmad b. Hanbal (d. 855). In keeping with their denial of God's attributes, the Muᶜtazila rejected the eternity of his speech, declaring the Koran to be an accident created in time and thus open to interpretation with respect to its outer and inner meanings. Influenced by the Hanbalis and other traditionists, the Abbasid caliph al-Mutawakkil (r. 847–861) rejected Muᶜtazilism and its theory of the created Koran, to which the Shiᶜis also subscribed. His opposition to Muᶜtazilism and Shiᶜism (exemplified by his destruction of the Shiᶜi shrine of the imam al-Husayn in Karbala) constituted a break with the past that initiated a new ethos of orthodoxy. The historian al-Masᶜudi (d. 956) described the caliph's policy:

> When the Caliphate came to Mutawakkil, he abolished free thought, philosophical disputes and the things which had occupied men's minds under Muᶜtasim, Wathiq and Maᶜmun [caliphs who had accepted Muᶜtazilism as the official doctrine of the Abbasid state]. He re-established orthodoxy and submission to traditional religious values, and insisted that the heads of the schools of Tradition should teach that Tradition and devote themselves to the propagation of the Sunna and practices sanctioned by the community of Islam.[13]

This orthodox trend also characterized the reign of the Abbasid caliph al-Muhtadi (869–870), who according to al-Masᶜudi "had made austerity and religion the twin aims of his life." Due to his puritanical simplicity the caliph broke musical instruments, rejected luxury objects, and obliterated painted figures from decorated rooms. The orthodox policy of the Abbasid caliphs was perpetuated in Baghdad, where they relocated their capital in the late ninth century. It culminated in the Sunni restoration that began to assert itself more strongly during the Buyid period from the reign of al-Qadir (r. 991–1031) onward. The Shiᶜi Buyids, under whose tutelage the Abbasid caliphs remained for more than a century between 945 and 1055 until the occupation of Baghdad by the Sunni Great Seljuqs, favored a combination of Muᶜtazili and Shiᶜi doctrines against which al-Qadir fought to restore the power of the caliphate. To this end he issued a manifesto in 1011 condemning the Fatimids in Egypt whose propaganda had penetrated the Shiᶜi quarters of Baghdad. After forbidding the teaching of Muᶜtazili and Shiᶜi doctrines in 1017, he promulgated the following year an official theology inspired by Hanbali ideas that condemned all unorthodox doctrines. In 1029 al-Qadir once again denounced Muᶜtazilism, particularly attacking its doctrine of the created Koran and affirming its status as an uncreated record of God's eternal speech.[14]

Sunni orthodoxy was firmly consolidated during the reign of the Great Seljuqs, a Turkish dynasty based in Iran and Iraq that associated its legitimacy with the freeing of the Abbasid caliphs from Buyid tutelage in 1055. This period produced such orthodox theologians as Abu al-Hasan al-Ashᶜari (d. 935–936) and al-Ghazali, who contributed to the restoration of Sunnism during the eleventh century. Unlike the Shiᶜi Buyids who had persecuted the Ashᶜari theological school, founded

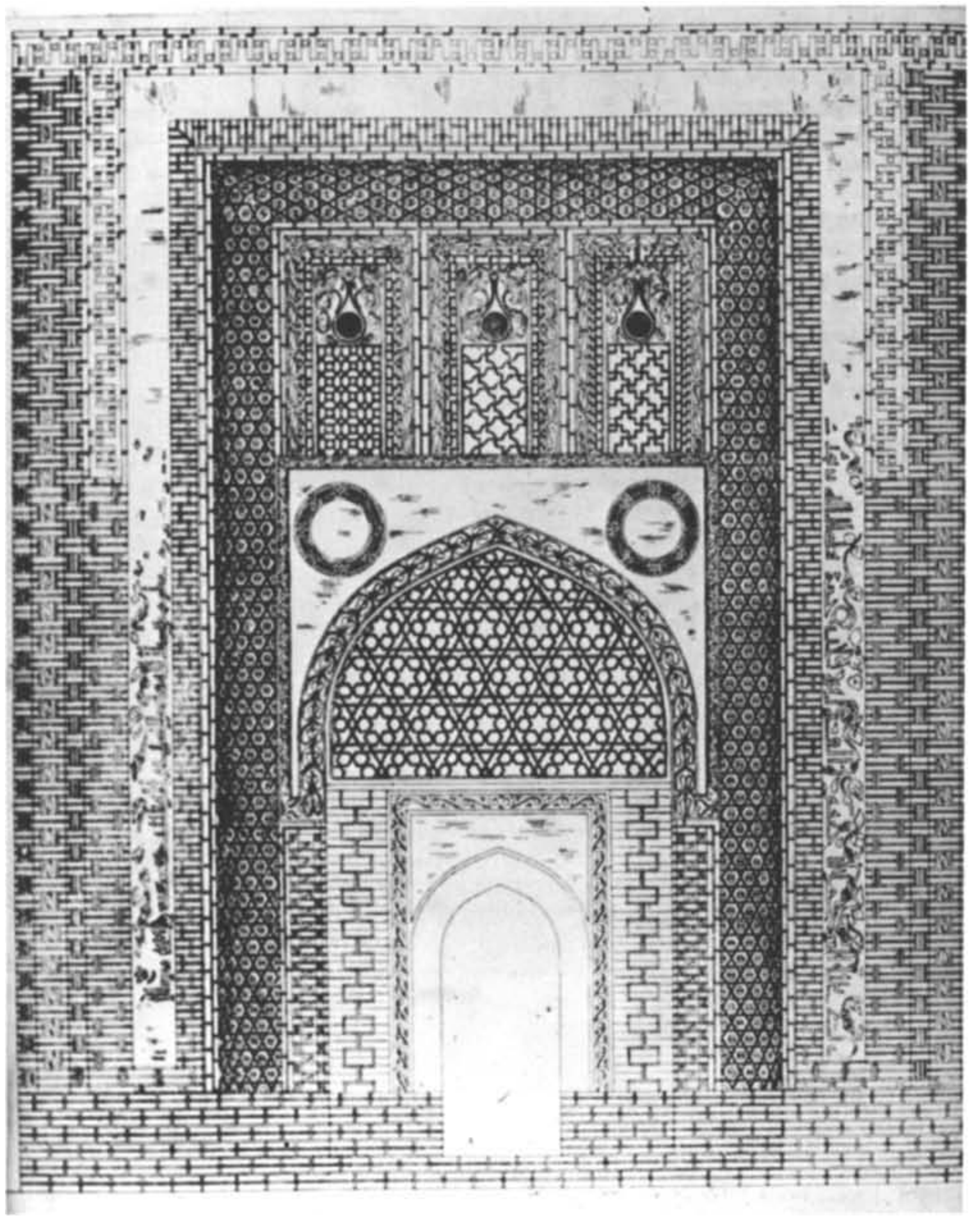
by al-Ashᶜari, the Seljuqs gave official support to it. The founder of this orthodox school of theology, who publicly denounced the Muᶜtazili doctrines to which he had previously subscribed, professed to follow the position of traditionists such as Ibn Hanbal, but defended his dogmatic theses through the type of rational argument employed by the Muᶜtazila.

The Ashᶜari theological school (generally allied with the legal school of al-Shafiᶜi) attempted to mediate between opposing views by its compromising middle path, or *via media*. It recognized the eternal attributes of God without accepting anthropomorphism, declared the Koran to be uncreated, and stressed God's omnipotence at the expense of human free will. It also modified the atomistic cosmology of the Muᶜtazila to vindicate the absolute power of God, the unique creator whose will alone guaranteed the perceived sense of order in the universe by preserving the accidental combination of atoms through continuous interference. This cosmology, refined by the Ashᶜari theologian al-Baqillani (d. 1013), ascribed to God's direct intervention not only the coming of things into being but also their persistence in being from one instant to another. It was used to support "arguments from design" that inferred God's existence through the wonderful design and composition observed in the divine creation. The universe reflected the wisdom and knowledge of an all-powerful God who had directly created it in time without any intermediaries, a theory differing from the Muᶜtazili and Shiᶜi view of the universe as an eternal emanation existing independently of God.[15]

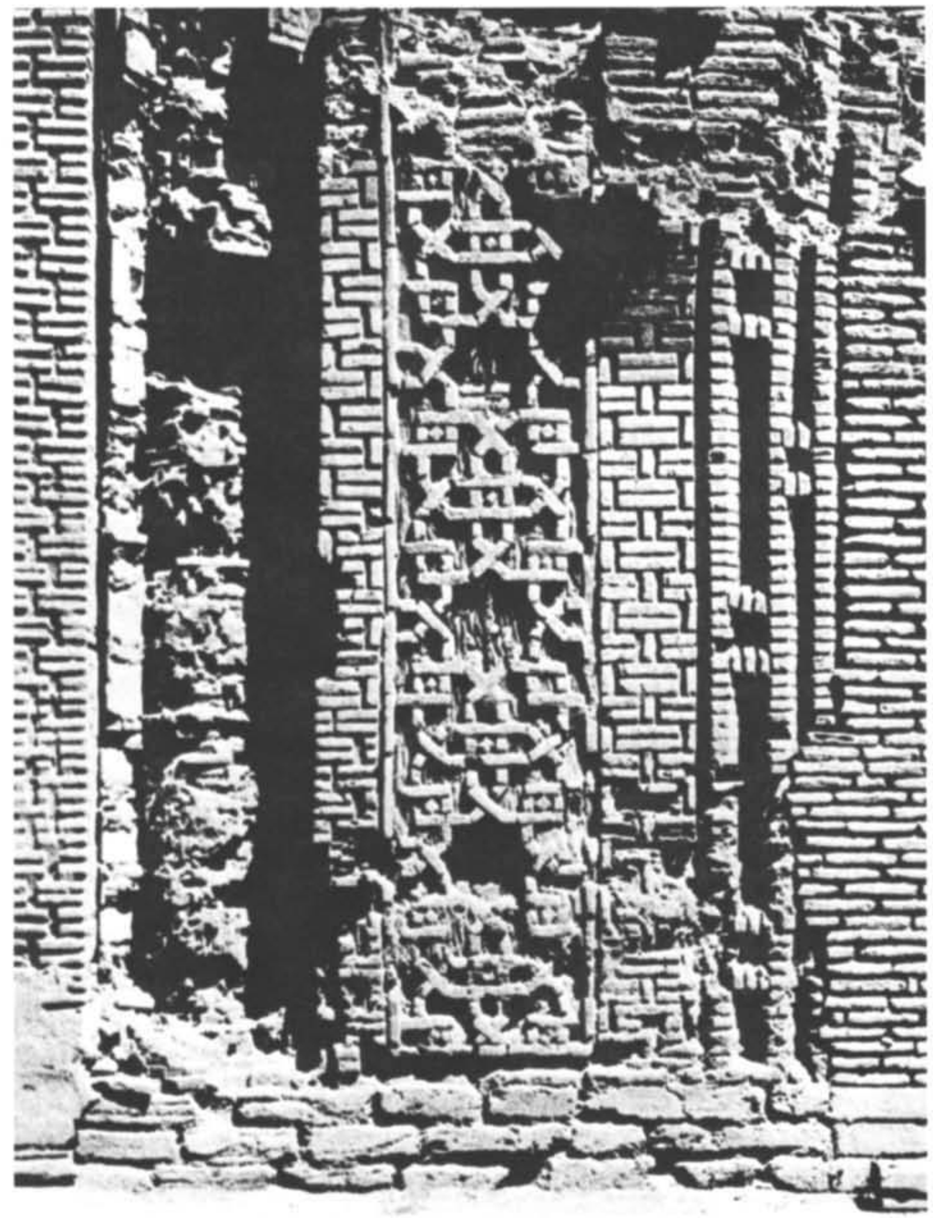
Al-Ghazali, the Ashᶜari theologian who worked under Seljuq patronage, was according to Ibn Khaldun "the first scholar to write in accordance with the new theological approach."[16] Known for his radical mistrust of human reason and his consequent condemnation of the views of speculative philosophers that were incompatible with orthodox Islam, al-Ghazali formulated a new synthesis of Ashᶜari Sunnism. This synthesis, a blend of traditional legalism, philosophical sciences, and moderate Sufism, encapsulated the "Shariᶜa-minded" ethos of the age of "Sunni revival" that eventually marginalized Muᶜtazili, Shiᶜi, and other unorthodox doctrines that had politically fragmented the Muslim world in the previous century. Despite the opposition it faced during the Seljuq period from the Maturidi school (which was particularly popular among the Hanafi Turks, a school that also defended orthodoxy by rational methods but found some of the Ashᶜari positions too conservative) and from the Hanbali traditionists (who rejected rational argumentation as an objectionable innovation), the Ashᶜari school became the dominant theological school in the Arabic-speaking parts of the late Abbasid caliphate. From that time well into the fourteenth century and beyond, the Ashᶜari school would become almost equated with Sunni orthodoxy in the Arab world, while the Maturidi school remained dominant in the Hanafi regions extending from Anatolia and Central Asia to India.[17]

It was in this context of Sunni revival during the hegemony of the Great Seljuqs that the *girih* mode suddenly flourished. Though its full potential for architectural revetments does not seem to have been realized until the eleventh century, the earliest formulation of its design principles probably took place in late tenth-century Baghdad from which it spread to other courts. The appearance of predominantly geometric revetments in Islamic architecture is usually traced to the tenth-century "brick style" of northern-northeastern Iran and Central Asia, from where it is thought to have migrated westward. However, this hypothesis is largely based on the accidental survival of the earliest brick buildings with geometric revetments in those regions, in contrast to the disappearance of monuments from the period of Buyid and Seljuq tutelage in the Abbasid capital Baghdad.

Early examples of the brick style from the tenth century, such as the Samanid mausoleum in Bukhara and the Buyid portal of the Jurjir mosque in Isfahan, are dominated by simple rectilinear geometric patterns that show no sign of the interlaced stars and polygons typical of the *girih* mode. Such patterns appear on the facade of the ᶜArab ᶜAta mausoleum (977–978) at Tim in Uzbekistan, a Qarakhanid monument whose interior has muqarnas units at its transition zone to the dome that signal the link between two- and three-dimensional geometric forms (fig. 88). The facade of another Qarakhanid mausoleum (1012–1013) in Uzgend in upper Ferghana (fig. 89), built for the ruler Nasr b. ᶜAli, also displays early examples of



88. Elevation drawing of entrance facade, mausoleum of ʿArab ʿAta, Tim, 977–978, ink on paper. Photo: Courtesy Harvard University, Fogg Art Museum, Fine Arts Library, Visual Collections.

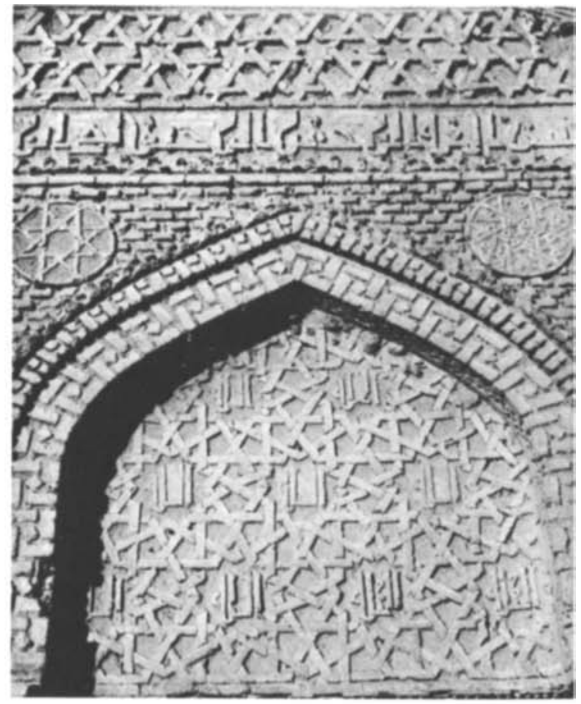


89. Detail of geometric brickwork on the main facade of a royal mausoleum, Uzgend, ca. 1012–1013. Photo: Copyright Ernst Wasmuth Verlag GmbH & Co. Tübingen/Berlin.

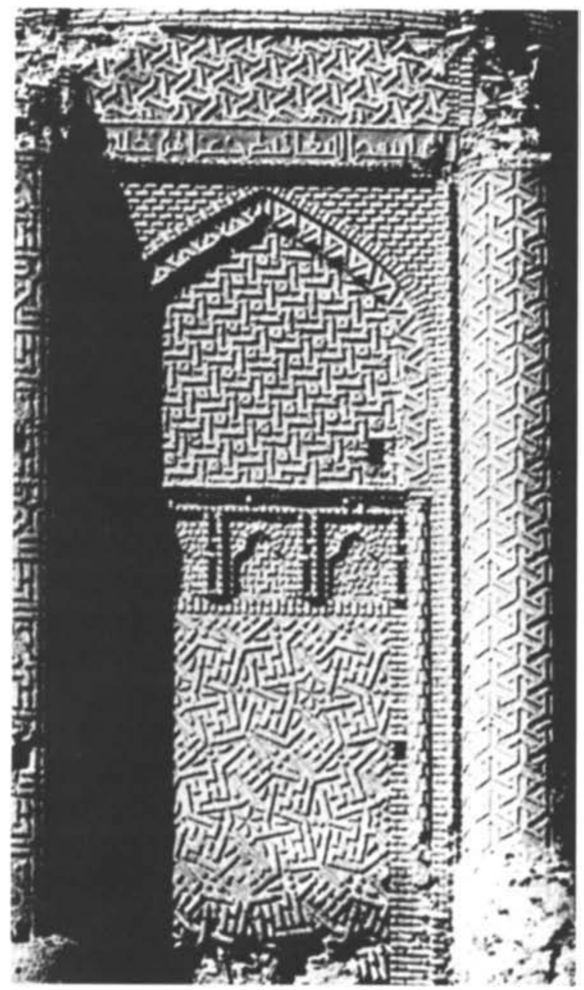
interlaced star-and-polygon ornaments in brick, seen on the eleventh-century brick minaret of that city as well. Such geometric patterns, often accompanied by the muqarnas, are consistently used on the brick monuments and minarets of the Seljuq domains after appearing in full-fledged form at two tomb towers in Kharraqan (1067–1068 and 1093) (figs. 90, 91). They are seen around the same time at the Great Mosque in the Seljuq capital Isfahan, with its two stellate dome chambers featuring muqarnas zones of transition (1072–1092 and 1088) and its various twelfth-century additions. The initial austerity of the geometric idiom in brick was soon loosened with the introduction of color in the tomb towers of Maragha and Nakhchivan in northwestern Iran including Gunbad-i Surkh (1147–1148), Gunbad-i Qabud (1196–1197), and Mu'mina Khatun (1186), whose elaborately superimposed, multilayered geometric strapwork patterns and muqarnas units are highlighted with turquoise-glazed bricks.[18]

That the earliest examples of architectural revetments employing the new geometric idiom should appear in such seemingly unrelated marginal areas as Tim, Uzgend, and Kharraqan is probably accidental. These revetments can reasonably be interpreted as regional echoes of innovations originating in the late Abbasid capital Baghdad, about which Herzfeld once wrote: "One must not underrate Baghdad, the seat of the caliphate and one of the seats of the Seljuq sultanate, as a cultural center down to its conquest by Hulagu in 656 H. (1258 A.D.). To underrate Baghdad is to underrate Rome." Baghdad, with its now-vanished late Abbasid and Seljuq monuments, is the most likely place from which two- and three-dimensional geometric revetments could have spread to neighboring courts. This hypothesis goes against the argument of such scholars as Diez, Oktay Aslanapa, and Selçuk Mülayim, who attributed the dissemination of geometric revetments to the nomadic tastes the Turks introduced from Central Asia to Iran and Anatolia. Pope, by contrast, interpreted the geometric mode that flourished during the Seljuq period as an Iranian creation rather than a Turkic one. These ethnonational interpretations fall apart under close scrutiny and fail to explain why and how similar geometric patterns spread so rapidly all the way from the eastern Islamic lands to Spain.[19]

While the Great Mosque in Isfahan is no doubt a mature example of the Iranian Seljuq brick idiom, its affinity with Baghdad, where the Seljuqs were simultaneously engaged in building activities, should not be underestimated. As Allen pointed out, "Baghdad was still the center of innovation in the ʿAbbāsid architectural tradition, even if the city was slowly declining in importance." Without denying the significance of the Seljuq capital Isfahan, Allen argued that "it makes sense to see the north dome of the Isfahan mosque as a sample of what was being built in Baghdad at the same time." He regarded the high quality of thirteenth-century brick buildings surviving in Baghdad as the final argument for the continued importance



90. Detail of geometric brickwork on the entrance facade of the East Tomb Tower (I), arch, spandrels, and inscriptions below dome, Kharraqan, 1067. Photo: Courtesy David Stronach.



91. Detail of geometric brickwork on one of the facades of the West Tomb Tower (II), full view below dome, Kharraqan, 1093. Photo: Courtesy David Stronach.

of that city as a cultural center. Such late Abbasid monuments in Baghdad as the Mustansiriya (1233) and the so-called thirteenth-century Abbasid Palace (with its sophisticated geometric revetments featuring superimposed star-and-polygon patterns and stellate muqarnases that dominate the geometrized vegetal motifs they frame) demonstrate the continuing vigor of the geometric mode after the termination of Seljuq rule in Iran and Iraq.[20]

Besides spreading throughout Iran and Iraq during the eleventh and twelfth centuries the geometric mode extended further east beyond the Seljuq domains, appearing in regions ruled by other Sunni dynasties who acknowledged the suzerainty of the Abbasid caliphs. It continued to be used in the Qarakhanid territories in Central Asia (e.g., the three royal mausoleums in Uzgend [1012–1013, 1152, and 1187], the Namazgah mosque in Bukhara [1119], and the fragmentary, twelfth-century Maghak-i ᶜAttari mosque in Bukhara). It also appeared in Afghanistan and India during the reigns of the staunchly Sunni Ghaznavid and Ghurid dynasties (e.g., the minaret of Masᶜud III [1099–1115] in Ghazna and the twelfth-century Ghurid arch at Lashkari Bazar in Bust). After the demise of the Great Seljuqs in 1194 predominantly geometric architectural revetments continued to spread in regions ruled by Sunni dynasties allied with the rejuvenated Abbasid caliphate. This was particularly the case with the splintered Seljuq successor states that ruled in Anatolia, northern Mesopotamia, Syria, and Egypt (e.g., Rum Seljuqs [1077–1307], Artuqids [1102–1408], Zangids [1127–1222], Ayyubids [1169–fifteenth century], and Mamluks [1250–1517]).

The princely rulers of these states, who had no claim for legitimacy other than the official sanction granted by the Abbasid caliphs in the form of titles and diplomas of investiture, played an important role in perpetuating the Sunni revival of the Great Seljuqs in an age that would increasingly turn to Sufism on the eve of the Crusades, followed by the Mongol invasions. The Zangid and Ayyubid policy of holy warfare (*jihād*) directed against the crusaders and the Fatimids restored Sunni power in Syria and Egypt, just as the Great Seljuqs had overthrown the Buyids in the east a century earlier. Interlaced geometric patterns accompanied by muqarnas friezes are prominently displayed on the earliest known examples of wooden minbars associated with the political legitimacy of the Seljuq successor states that revived the Abbasid *khuṭba*, that is, the Friday sermon during which the name of the reigning caliph in Baghdad was pronounced from the minbar as a sign of homage. These include the minbar of the ᶜAla' al-Din mosque in the Anatolian Seljuq capital of Konya (1155) and the ones installed by the Seljuq *atabeg* (tutor assigned to Seljuq princes governing in the provinces) Nur al-Din Zangi at his mosque in Hama (1163–1164) and at the Great Mosque of Aleppo (1169). (The latter was reinstalled at the Aqsa mosque in Jerusalem by the Ayyubid ruler Salah al-Din [1138–1193] after the conquest of that city from the crusaders in 1187.)[21]

Geometric strapwork and the muqarnas, not widely used in the Fatimid territories of Syria and Egypt before, suddenly proliferated in those regions under Zangid, Ayyubid, and Mamluk rule. The carved stone decorations of Fatimid religious monuments and their accompanying woodwork had been dominated by vegetal patterns, intertwined with floriated Kufic inscriptions. Just as the muqarnas is only rarely used in Fatimid religious architecture, so are interlaced star-and-polygon patterns, which appear in a few isolated examples. Geometric patterns that hesitantly trickled into Egypt from Syria were not typical of the predominantly vegetal Fatimid decorative vocabulary. As Jonathan Bloom observed, muqarnas vaults and portals with true muqarnas hoods would remain unknown in Egypt until they were introduced from Syria by the Mamluks in the mid-thirteenth century. The hospital (1154) and funerary madrasa (1167–1168) of Nur al-Din Zangi are the earliest buildings in Damascus that imported the Iraqi conical muqarnas dome and portal with a muqarnas hood, framed by a matching border of interlaced star-and-polygon patterns.[22] Two- and three-dimensional geometric revetments continued to be elaborated by the Ayyubids when they succeeded the Zangids and by the Mamluks, who perpetuated the Sunni legacy of their Ayyubid masters by maintaining in Cairo a line of Abbasid caliphs to legitimize their rule after the Mongol sack of Baghdad in 1258.

The geometric mode also permeated the Anatolian monuments of the Rum Seljuqs, a

dynasty that boasted direct royal descent from the Great Seljuqs, unlike other neighboring Seljuq successor states mostly founded by former *atabegs* or by slaves and descendants of *atabegs*. Geometry appears more conspicuously in Anatolia than in the monuments of Syria and Egypt built around the same time. The emblematic two- and three-dimensional geometric patterns prominently displayed on the early thirteenth-century stone portals of Rum Seljuq monuments, with their muqarnas hoods framed by borders of interlaced stars and polygons, advertised the connection of the ruling dynasty with Iran and Iraq. Given the close affinity of these geometric patterns with the ones decorating the contemporary brick monuments of thirteenth-century Baghdad, they also may have alluded to the alliance between the Rum Seljuq sultanate and the late Abbasid caliphate, an alliance that echoed the earlier Great Seljuq pattern.[23]

The notable resistance to the geometric mode in areas dominated by the legacy of the Fatimid and the Spanish Umayyad caliphs provides support for the close association of its emblematic forms with the rival Abbasid caliphate and its vassals or allies. It is therefore not a coincidence that geometric patterns and the muqarnas spread from the east to North Africa and Spain during the reign of the Almoravids (1056–1147), who politically united these two regions and recognized the Abbasid caliphs as the spiritual leaders of Islam. The few surviving examples of Almoravid monuments where such two- and three-dimensional geometric patterns appear together with richly intertwined vegetal motifs include the Qarawiyyin mosque in Fez, which was remodeled in 1135–1144, and the Qubba in Marrakesh bearing an inscription from the reign of ᶜAli b. Yusuf (r. 1106–1142). In return for including the name of the Abbasid caliph on their coinage and in the *khuṭba*, the Almoravids were recognized by the caliph as the legitimate rulers of the Maghrib. This Berber dynasty, which followed the Maliki legal school that was prominent in the Maghrib, espoused a Sunni revival of its own directed against the Shiᶜi heritage of the Fatimids and their vassals, who had previously dominated North Africa. The militant ethos of this dynasty that targeted the Christian reconquest of Muslim Spain paralleled the policy of *jihād* against the crusaders adopted by the Zangids and the Ayyubids in a similar political climate where Shariᶜa-minded Sunni orthodoxy was enforcing its redefined norms. The local dynasties that succeeded the Almoravids would firmly establish Sunnism in the Maghrib. As Ibn Khaldun noted in the fourteenth century, the "heretics and innovators" had so successfully been eliminated by then that students no longer had to study "the science of speculative philosophy" that had once been useful in arguing against heretical doctrines.[24]

Though they dissociated themselves from the Abbasids, the Berber Almohads (from *al-Muwaḥḥidūn*, "those affirming God's oneness"), who succeeded the Almoravids in North Africa and Spain (1130–1269), furthered the consolidation of Sunni orthodoxy. Their reformist founder, Ibn Tumart (d. 1130), had been influenced by the Ashᶜari theology of al-Ghazali that approached religion through logic and encouraged the diffusion of moderate Sufism. Adopting the Ghazalian synthesis of Sufi-oriented Sunnism, Ibn Tumart espoused a fundamentalist form of asceticism that condemned luxury and aimed to restore the purity of early Islam. Almohadism placed severe restrictions on architectural ornament, purging the extravagant Almoravid revetment aesthetic by reducing it to boldly enlarged geometrized basic essentials with precise and well-defined linear patterns on plain backgrounds, accompanied by the ubiquitous muqarnas. Almoravid monuments were either destroyed or their densely intertwined ornate decorations were covered with plain white plaster—in the case of the Qarawiyyin mosque in Fez, fearful inhabitants whitewashed its polychromatic plaster ornaments featuring gilded paintings the night before the Almohad conquerors, who preached austerity, entered their mosque for the Friday prayer. The visual asceticism of the Almohads was not unlike that of the Cistercians, articulated in the *Apologia*, circa 1123–1127, of Bernard of Clairvaux (1090–1153) that opposed luxurious monastic art just around the same time.[25]

Before the infiltration of Almoravid and Almohad influences from North Africa, the architectural decoration of monuments sponsored by the Spanish Umayyads (756–1031), and the eleventh-century Taifa kings of Spain who emulated them, had been dominated by a Byzantiniz-

ing vegetal vocabulary to which geometric motifs were subordinated. The classical flavor of pre-eleventh-century Islamic architectural ornament in this region, alluding to the prestigious seventh- and eighth-century Syrian Umayyad imperial heritage of the Spanish Umayyad caliphate, articulated a separate dynastic identity that resisted the Samarran beveled aesthetic and later Abbasid decorative idioms. The geometric mode and the muqarnas only reached Muslim Spain after its unification with North Africa under the Berber dynasties between the late eleventh and thirteenth centuries. The relative novelty of this mode for the Andalusian traveler Ibn Jubayr (b. 1145) can be deduced from his enthusiastic description in 1182 of Nur al-Din's joined woodwork minbar at the Great Mosque of Aleppo.[26]

Two- and three-dimensional geometric patterns underwent an internal development in North Africa and Spain, culminating in the refined polychromatic revetment aesthetic of the Alhambra. Reacting to the ascetic decorative vocabulary of their Almohad predecessors, the Nasrids who ruled in Andalusia reintroduced luxurious and richly gilded intricate revetments to proclaim their different dynastic identity. As Grabar noted, the Alhambra stood "at the end of a historical development" and represented "despite all its perfection, a formal dead end" that "crystallized the possibilities as well as the limits" of a medieval Islamic decorative tradition. Sponsored by the culturally isolated Nasrid dynasty, which would eventually be expelled from Spain, the Alhambra featured precious geometric reveries that were romantically embedded in the memory of a glorious past age.[27] These intricate ornamental fantasies that so fascinated the Orientalists were perpetuated without much creative renewal in the Mudejar style of Spain and in the architecture of Morocco until modern times. Paccard's work on the traditional crafts practiced in Morocco provided the Arabic names given today by master builders to arabesques composed of curvilinear vegetal patterns (*al-tawrīq*, "leafed") and polygonal geometric interlaces (*al-tastīr*, "delineated or ruled with lines"), accompanied by calligraphy and the muqarnas. The same masters referred to star-and-polygon patterns as *ʿuqda* (Arabic, "knot"), corresponding to the term *girih* (Persian, "knot") that is more common in the Islamic east.[28]

After the Mongol invasion of Anatolia in 1248, followed by the sack of Baghdad in 1258, a novel decorative vocabulary infiltrated the eastern Islamic lands during the second half of the thirteenth century, when the geometric idiom lost its initial purity and was diluted by a host of new patterns. The abstract repertory of medieval Islamic patterns was now enriched by an influx of East Asian motifs thanks to contacts brought about by the Pax Mongolica when Yuan China and Ilkhanid Iran were joined together for more than half a century under Mongol rule. As vassals of the Great Khan, the Mongol-Ilkhanids introduced into Iran and Anatolia novel chinoiserie motifs (e.g., blossoms, lotuses, peony scrolls, cloud bands, lobed panels, dragons, phoenixes, and other auspicious mythical creatures) that would forever transform the eastern Islamic decorative language.[29] Vegetal, geometric, calligraphic, and figural patterns now became integrated into a new visual idiom testifying to the dynamic synthetic capacities of Islamic art. This transformation did not escape the perceptive eye of Riegl, who noticed the appearance of more naturalistic tendencies in the vegetal ornament of later Islamic art. This he attributed to the "Asiatic tribes of Turkic origin" who ruled Anatolia and the Iranian world. Herzfeld and Kühnel also noted the evolution of the arabesque toward greater realism in the post-Mongol eastern Islamic lands influenced by Central and Eastern Asia.[30] Referring to the vegetal arabesque, Kühnel wrote:

> In the middle of the thirteenth century, its position was so strong that it escaped the danger of being swept away by the flood of Far Eastern motifs which came with the Mongol invasion. However, from now on the arabesque no longer exclusively ruled the imagination of the designers whose creative power had become newly fertilized with other ideas.[31]

The so-called geometric arabesque, then, had emerged sometime around the late tenth and early eleventh centuries in the eastern Islamic lands from where it spread between the eleventh and early thirteenth centuries. We have seen that this process of dissemination before the arrival of

the Mongols was intimately correlated with the dynamics of the Sunni revival, although the nature of that correlation does not appear to have been articulated in the written primary sources. The crystalline perfection of clearly delineated, legible geometric forms represented a new visual idiom radically different from the ambiguously undulating curvilinear aesthetic of ninth-century Samarra. As in Samarra entire surfaces continued to be covered in tilelike fashion with infinitely extendable repeat units whose ingeniously interpenetrating abstract shapes, which seemed capable of continual metamorphosis into one another, once again blurred figure-ground distinctions. Now, however, their formal taxonomy was severely limited to algebraically definable, angular geometric shapes such as triangles, quadrangles, circles, polygons, star polygons, and their fragments. These shapes forming intricate geometric interlaces owed their distinctive appearance to the use of dynamic radial grid systems whose rotational symmetries were far more complex than their late antique and early Islamic counterparts, which were based on simpler rectilinear grids with diagonal coordinates.

The novel interlaced star-and-polygon patterns, consisting of periodic tilings (or tessellations) whose lines (or edges) met at vertices constituting "knots," found both planar and spatial expressions. It was as if the amorphousness of the beveled style suddenly became disciplined into intelligible linear patterns obeying the rhythms of an implicit geometric order that governed the compositions of interrelated geometric, vegetal, and calligraphic patterns alike. This order was made more explicit in geometric interlaces generated by underlying networks of grid lines, some parts of which appeared in the final pattern while others were eliminated by erasure. The resulting compositions, created by an intractable process of selection and rejection, concealed partly invisible grids that resisted decipherment and as such testified to the ingenuity of their designer.

The clarity of sharply delineated polygonal patterns with a hidden geometric basis, as opposed to the deliberate obscurity of the enigmatic Samarran style, introduced a new structure of legibility to abstract ornament. Ingeniously interlaced geometric patterns now manifested an underlying sense of order with their mathematically grouped and infinitely extendable star systems clustered like orbits around multiple foci. Could they have been intended as abstract visual analogues for the rhythmic order of a divinely created atomistic universe, constantly kept in check by an all-powerful God whose wisdom was manifested in the wonders of creation? According to the philosopher and physician Ibn Rushd (Averroes, 1126–1198), the adherents of the Ashᶜari school who "held that all things could be different from what they are," nevertheless recognized that "in the products of art, to which they compared the products of nature, there exist order and proportion, and this was called wisdom, and they called the Creator wise." Al-Ashᶜari wrote: "Well-made works can be wisely ordered only by one who is knowing. That is clear from the fact that a man who lacks skill and knowledge cannot weave patterned brocade or execute fine points of craftsmanship."[32]

By implication the divinely created Ashᶜari atomistic universe (shared by the Maturidi school) was permeated with a harmony that resonated with two- and three-dimensional geometric patterns, generated by undecipherable grids evoking a sense of wonder. Since God and the contents of God's eternal speech embodied in the uncreated Koran were beyond imitation, artists had no recourse but to turn to the abstract imitation of the created realm of nature extending from the upper limits of the heavens to the earth below, a realm replete with the indirect signs and portents of God's wisdom and infinite power. Geometrized nonfigural arabesques apparently modeled on inanimate matter and vegetation, that is, on two of the three kingdoms of nature (*al-mawālīd al-thalātha*, "mineral, vegetable, and animal"), seemed to evoke a new sense of order missing from the unstable atomistic material world of the Muᶜtazila.[33]

It is tempting to correlate the stringent geometrization of nonfigural patterning, through the logical coherence and crystalline clarity of a linear geometric language, with the puritan sensibilities of the age of Sunni revival during which it flourished. Ibn Khaldun, who like al-Ghazali attacked speculative philosophy, described geometry as a mental astringent capable of clearing error from one's mind like soap:

> It should be known that geometry enlightens the intellect and sets one's mind right.

> All its proofs are very clear and orderly. It is hardly possible for errors to enter into geometrical reasoning, because it is well arranged and orderly. Thus, the mind that constantly applies itself to geometry is not likely to fall into error. . . . Our teachers used to say that one's application to geometry does to the mind what soap does to a garment. It washes off stains and cleanses it of grease and dirt. The reason for this is that geometry is well arranged and orderly, as we have mentioned.[34]

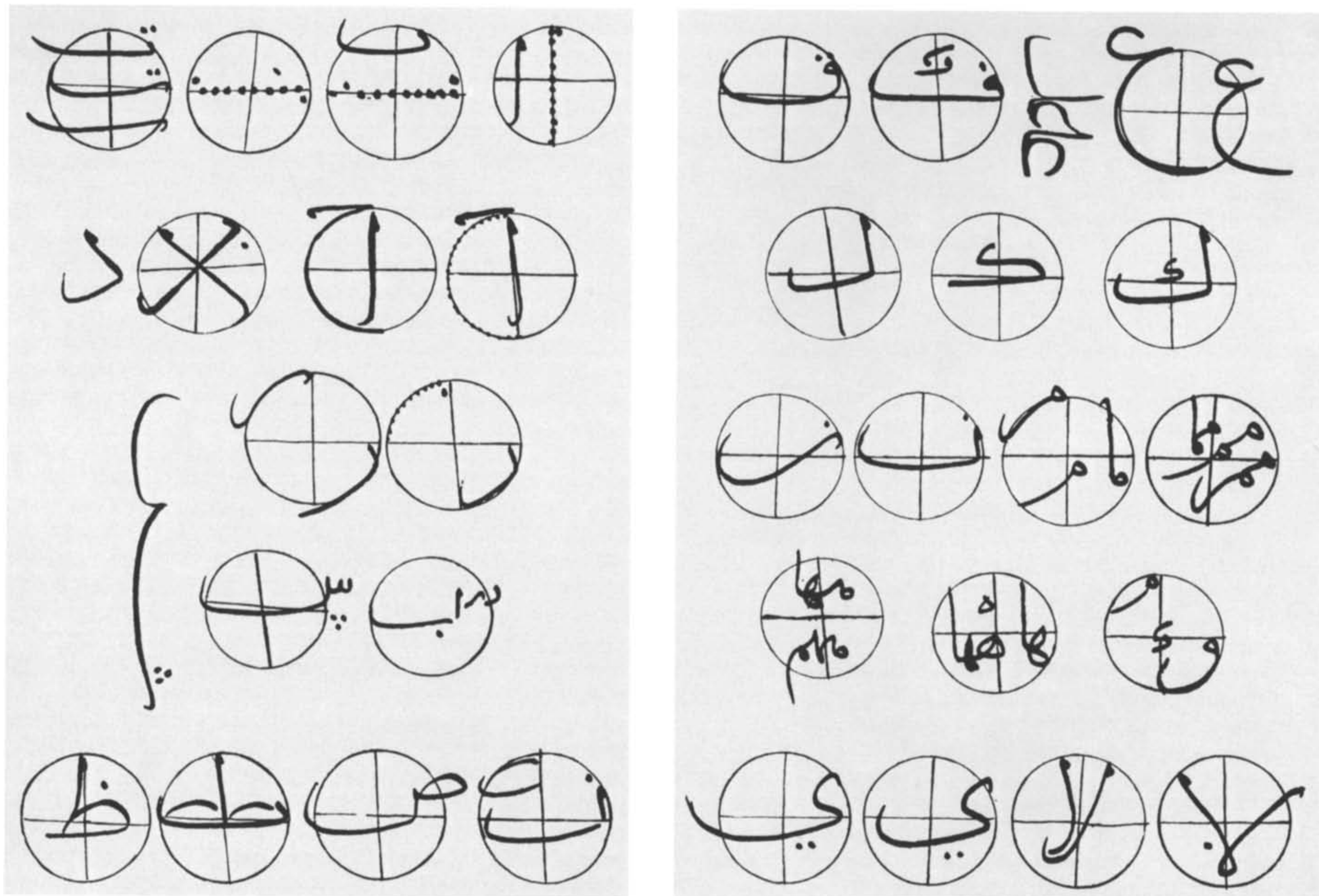
This statement reflects the distinction such orthodox scholars as al-Ghazali had drawn between those philosophical sciences such as mathematics and logic, which were innocuous from a religious point of view, and others such as physics and metaphysics, which contained the bulk of the heresies and errors of the speculative philosophers.[35]

The "pure" forms of geometry, associated with the certainty of proofs, must have made geometric abstraction a particularly appealing visual idiom during the age of the Sunni revival when religious orthodoxy was defended through logical argumentation to make faith "clearer" by an appeal to reason. The unambiguous language of geometry that expressed logic in linear relations can, therefore, be seen as a visual analogue of the new quest for certainty aimed to eliminate the doubts and uncertainties previously raised by philosophical speculation. The official Sunni ideology had now closed its doors to rationalistic interpretation, substituting a clearly manifest dogmatic theology supported by logical argumentation and tradition. Reason no longer reigned supreme in this new orthodox blend of dogmatic theology, traditional legalism, and moderate mysticism but became subordinated to subrational experiential categories such as inspiration, insight, intuition, and love in the metaphysical quest for truth. Geometric abstraction, therefore, resonated not only with the puritanism of the traditionists but also with the mysticism of the Sufis, permeated with echoes of Neoplatonism. The harmoniously proportioned forms of geometry, capable of purifying the mind and purging one's understanding from error, moreover had the unique power of mediating the material and sensible worlds through their intermediary status between the two, as we shall see in part 5. Though they remained bound to the material world of accidents, the mentally abstracted forms of geometry were seen as capable of inducing the spirit to contemplate higher levels of understanding, a noetic quality that must have been particularly appealing in a context that blended Sunnism with elements of mysticism.

The time and place in which the *girih* originated cannot conclusively be proven with the present state of the archaeological record, but the indirect evidence strongly points to the late Abbasid court in Baghdad, the center where the aesthetically related field of calligraphy became codified. It was in Baghdad that the proportional system of the six Arabic canonical scripts, first codified by the Abbasid vizier and calligrapher Ibn Muqla (886–940), was perfected by the Buyid period calligrapher and illuminator ʿAli b. Hilal (Ibn al-Bawwab, d. 1022), who further refined the "proportioned script" (*al-khaṭṭ al-mansūb*) rooted in the principles of geometric design. The geometric system of proportioning devised by Ibn Muqla had been based on the modular use of rhombus-shaped dots created by the reed pen, with each letter standardized in proportional relation to the straight line of the alif. His relatively angular semikufic Koranic script was improved by the fully cursive one of Ibn al-Bawwab that contemporary critics judged to be more legible and more elegant. The latter's proportional system—further refined in Baghdad during the reign of the last Abbasid caliph by the calligrapher Yaqut al-Mustaʿsimi (d. 1298–1299)—was generated by the use of the circle and its diameter (subdivided into modular dots) as a unit of measure (fig. 92).[36]

The invisible geometry that governed the proportions of these new scripts codified in the chancelleries of Baghdad recalls the underlying geometric schemes used in generating abstract geometric and vegetal patterns with which they are often juxtaposed on manuscripts, objects, and buildings. The use of the circumference and radius of the circle as a proportioning device in both Ibn al-Bawwab's cursive Koranic script and in *girih* patterns represents related aesthetic phenomena that seem to have originated in the same milieu. The new cursive script and interlaced patterns composed of stars and polygons appear juxtaposed for the first time in a Koran at the Chester Beatty

92a, b. Muhammad b. ᶜAli b. Sulayman al-Rawandi, diagrams showing the derivation of cursive Arabic letters from the module of the circle and its diameter subdivided by dots. From his *Rāḥat al-ṣudūr wa āyat al-surūr* (Solace of hearts and signal for gladness), 1238, ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 438.



93. Illuminated frontispiece. From the Ibn al-Bawwab Koran, Baghdad, 1000–1001, colored inks and gold on paper. Reproduced by the courtesy of the Trustees of the Chester Beatty Library, Dublin, MS K.16, fol. 8r.

Library in Dublin, whose colophon states that it was written in Baghdad during 1000–1001 by the calligrapher and illuminator ʿAli b. Hilal (fig. 93). Even though this colophon is thought by some to be apocryphal, it is safe to date the manuscript, popularly known as the Ibn al-Bawwab Koran, to the early eleventh century. Its frontispieces—on which the cursive Koranic script, interlaced geometric strapwork patterns, and abstract vegetal motifs harmoniously intertwine—are thought to have been executed by the same hand. This suggests that the *girih* mode could have made its first appearance in manuscript illumination, a hypothesis strengthened by the well-known impact that patterns drawn on paper in royal scriptoria had on the decorative arts and architectural revetments of later periods. Several early Korans with fully cursive scripts feature similar angular geometric interlaces whose compartments contain abstract vegetal patterns, a combination that came to be a standard characteristic of fourteenth-century Mamluk and Ilkhanid illuminated Korans.[37]

As Yasser Tabbaa noted, the new Koranic script codified by Ibn al-Bawwab constituted "a final break with the majestic but ambiguous script of the first three Islamic centuries, replacing it with a robustly cursive and perfectly legible script." He related this development to the religious and political climate of Buyid Baghdad, where the Sunni revival initiated by al-Qadir had affirmed the uncreated nature of the Koran to oppose the Shiʿi and Muʿtazili view that regarded it as having been created in time and therefore open to rationalistic or esoteric interpretation. Tabbaa pointed out the difference between the notion of a mysterious created Koran with two levels of meaning intended to "be interpreted by those who know for those who do not" and of an uncreated eternal one whose "clearly manifest truth cannot be further interpreted." He convincingly argued that the Ibn al-Bawwab Koran "represents the creation of a perfectly cursive and easily legible script suitable for expressing the clear and explicit nature of the Word of God." Tabbaa concluded that "at the time of its inception and particularly its adoption throughout the only recently Sunni Islamic world," the proportioned script "literally reflected the triumph of a theological view and all its political ramifications. The actual image—not just the content—of the Word became the symbol of the most important principle of the Sunni revival, a movement that redefined the course of medieval Islam."[38]

It is probably not a coincidence that the geometric mode that emerged in the same context was also characterized by the linear clarity and precise logic of its forms. Predominantly geometric interlaces are often accompanied on wooden minbars and religious monuments with disciplined vegetal patterns, cursive scripts, and the muqarnas, all of them governed by similar underlying geometric grids. Tabbaa's observation that the cursive scripts of Ibn Muqla and Ibn al-Bawwab had virtually no impact on Korans produced in Fatimid Egypt, where the earlier type of kufic script continued in use until the establishment of the Ayyubid dynasty, is in keeping with the pattern of dissemination followed by two- and three-dimensional *girih*s that similarly echoed the rhythms of the Sunni revival. The same pattern of dissemination guided the spread of cursive monumental inscriptions, which eventually supplanted the Fatimid floriated kufic script between the eleventh and thirteenth centuries.[39]

Given the close affinity between two- and three-dimensional geometric patterns, it is not surprising that several scholars have recently posited a Baghdadi origin for the muqarnas. Tabbaa, for example, accepted Iraq as the most likely place for the emergence of the muqarnas vault, the earliest surviving example of which appears in the Imam Dur (1075–1090) near Samarra, a hypothesis further strengthened by the fact that it was a very common feature of the cityscape of medieval Baghdad. Allen similarly identified the muqarnas vault as an invention of Abbasid architecture, "devised in Iran or Iraq and copied all over the Islamic world." He regarded Imam Dur's "sugar-loaf dome" as representing the original use of the form that was subsequently adapted to squinches and cornices. Taking the evidence of some painted stucco muqarnas units discovered at a bath in Fustat, which recall the possibly tenth-century painted stucco muqarnas niches excavated at Nishapur, Doris Behrens-Abouseif reached a similar conclusion. She argued that if the Fustat muqarnas units are to be attributed to the Abbasid rather than the Fatimid period as commonly assumed, in that case "Baghdad as the capital of

the Abbasid empire, could well be the place of origin of the *mukarnas*."[40]

If so, Baghdad emerges as the main center for synchronous developments in interrelated fields of geometric design, the center from which artistic innovations rapidly spread to those courts culturally and politically committed to the Sunni revival. The trajectory of the *girih* mode over time and space, then, was far more complex than assumed in the literature on the arabesque, which tended to minimize the visual difference between various abstract idioms and to associate them with a loosely defined religious mentality responsible for the overall unity of Islamic art. We have seen, however, that there was no single interpretation of Islam, or of its central doctrine of *tawḥīd,* that remained uncontested. Such controversial issues as the nature of God (framed within a wide spectrum defined by the opposing poles of anthropomorphism and the complete divestment of attributes), the role of human reason, and the createdness versus uncreatedness of the atomistic material world and of the Koran constituted significant points of departure for sectarian differences in a politically and ideologically divided medieval Muslim world. Rather than a single doctrine and cosmology that gave rise to uniformity in artistic expression throughout the Islamic world, there was a multiplicity of competing doctrines and cosmologies that informed the formulation of diverse visual idioms in different court milieus.

I have only briefly outlined some of the dominant theological orientations that were part of the context in which the geometric mode initially emerged and spread, in order to give a sense of the ideological complexity of religious dogma that often went hand in hand with politics. No doubt a more detailed analysis of contemporary legal, theological, philosophical, and mystical sources will in the future contribute to a more nuanced reading of the subtle correspondences between dominant official ideologies and visual idioms, particularly since the Sunni revival was by no means unilinear. We have seen that Sufism, with which so many authors automatically correlated the arabesque, was not yet a prominent cultural force among the ruling elites who patronized art and architecture at the time the *girih* first appeared. Even though it had started to penetrate into orthodox circles and to be formally organized into confraternities from the twelfth century onward, its impact on visual aesthetics at that time appears to have been rather limited. Much more than the spiritualism of Sufism, it was the Shariᶜa-minded scripturalism of the Sunni revival that dominated the milieu where the *girih* came into being.

Moreover, the type of moderate Sufism that prevailed in orthodox circles at that time was very different from the more daring teachings of Ibn al-ᶜArabi or Shihab al-Din al-Suhrawardi (1153–1191) with which modern authors often link the arabesque. Al-Suhrawardi, the Iranian master of illumination (*ishrāq*) who developed a philosophy of divine light as the sole substance of being, was after all charged with heterodoxy and killed by the order of the Ayyubid ruler Salah al-Din. Though Ibn al-ᶜArabi, who settled in Ayyubid Damascus after having visited the Rum Seljuq court in Konya, did not suffer a similar fate, he certainly was not free of orthodox hostilities. For example, Ibn Taymiyya (1263–1328), the reactionary Hanbali theologian of the Mamluk period, would vehemently condemn Ibn al-ᶜArabi's monism, which regarded the existence of created things as nothing but the very essence of the creator. Similarly Ibn Khaldun found his mystical writings meaningless and heretical. Ibn al-ᶜArabi's teachings would gain much wider currency during the post-Mongol era, particularly in the Turco-Iranian world, but they were far from unanimously accepted in orthodox circles during the high tide of the Sunni revival.[41]

The geometric mode seems to have represented a new visual order projecting a shared ethos of unification around the religious authority of the Abbasid caliphate, the locus of orthodoxy and the ultimate source of legitimacy for the fragmented Sunni states. It was as if the ideological alliance between the Abbasid caliphs and the semi-independent Sunni rulers of the decentralized medieval Islamic world was expressed through the rapid dissemination from Baghdad of emblematic signs that acted as a semiotic bond visually uniting distant regions.[42] Just before the Mongol sack of Baghdad, which shattered this brief sense of unity that lasted between the eleventh and early thirteenth centuries, the Abbasid caliph al-Nasir li-Din Allah (r. 1180–1225) restored the secular power of the caliphate after centuries of Buyid and Seljuq domination. His religiopolitical program

was aimed at orienting all Muslims to the Abbasid caliphate as the sole spiritual and secular center of the Islamic world. To this end he attempted to bring about a rapprochement of opposing dogmatic trends in Islam and thereby create a compromise between the Sunnis and Shiʿis. Al-Nasir's new ideological orientation was more concerned with equating all Islamic confessions than with unifying the Sunnis against the Shiʿis, Muʿtazilis, or the invading Christians. The caliph's propagandist ʿUmar al-Suhrawardi (d. 1234), a Sufi theologian of the Shafiʿi school, energetically supported the union of Sunnism and moderate Shiʿism by positing that Sufism, a mediating bridge between those two poles, could be sanctioned by the caliphate. This view, which turned the Abbasid caliph into the focal point of the Shariʿa and Sufism, consolidated the synthesis initiated in the Seljuq period by al-Ghazali. After years of distrust by the ruling powers, orthodox Sufism thus found its way into Sunni circles with an official sanction by the caliphate.[43] Al-Nasir's reign therefore prepared the ground for the rising fortunes of Sufism during the post-Mongol era, when the traditional hostility between the Sunnis and Shiʿis would become much less acute after the fall of the Abbasid caliphate in Baghdad.

During the Mongol-Ilkhanid period the mitigation of the Sunni-Shiʿi dispute in the eastern Islamic world was accompanied by the strengthening of Twelver Shiʿism, the increasing appearance of Shiʿi trends in Sufism, and a leaning toward moderate Shiʿism in Sunni circles. This climate of rapprochement would be perpetuated in the post-Mongol Turco-Iranian world throughout the fifteenth century until the repolarization of Sunni-Shiʿi differences along political lines with the sixteenth-century rise of the three early modern empires, the Sunni-Hanafi Ottomans and Mughals versus the Twelver Shiʿi Safavids. According to Biancamaria Scarcia Amoretti, prior to that realignment, the "promiscuous" religious topography of the post-Mongol eastern Islamic world that extended all the way from Anatolia to India was characterized by a certain ambivalence, "so that belonging to the Shiʿi rather than to the Sunni confession would seem to be a matter of religious sensibility rather than one of ideological divergences or different juridical rites." In this tolerant setting deeply imbued with Sufism, which helped bridge religious differences, it was not uncommon for Ilkhanid, Timurid, and Turkmen rulers to waver between Sunnism and Shiʿism according to personal convictions.[44] The Timurid-Turkmen context in which the Topkapı scroll seems to have been compiled was, then, a very different setting from the staunchly orthodox, puritan milieu of the Sunni revival in which the geometric mode had initially flourished.

CHAPTER 7. THE POST-MONGOL SYNTHESIS

The continued life of the *girih* mode in the post-Mongol era seems to have been propelled by its own formal momentum as it became assimilated into workshop traditions through the codified repertories of scrolls. Now merged with the Chinese-flavored aesthetic synthesis of the Mongols and their successors, it was accompanied by a wide variety of motifs. Whatever original associations it may have carried with the Sunni revival were largely forgotten and substituted with new ones. The Mongol invasions brought about a cultural split between the Turco-Iranian realms in the east (extending from Anatolia to the borders of China) and the Arab-speaking ones in the west (extending from the Mamluk territories to North Africa and Spain), a split reflected in the different decorative vocabularies that prevailed in each region. The antinaturalistic abstract language of geometric, vegetal, calligraphic, and figural patterns was perpetuated in the Arab world, which had successfully resisted military invasion by the Mongol forces. Although the Mamluks, situated at the transitional zone between the eastern and western Islamic lands, selectively incorporated some of the new floral chinoiserie motifs into their traditional decorative vocabulary that conservatively preserved its visual link with the caliphal "golden age," the post-Mongol aesthetic synthesis of the east had very little impact in North Africa and Spain, where a separate cultural identity was cultivated by local dynasties that nostalgically clung to the past. This nostalgic cultural orientation was politically expressed by the continued role of the Abbasid caliphs stationed at Mamluk Cairo in distributing titles to such loyal rulers as the Nasrids and the slave sultans of Delhi.

The post-Mongol visual idiom that stamped the decorative arts and architectural revetments of the eastern Islamic world spread in Iran, Iraq, Anatolia, and Central Asia during the late thirteenth and fourteenth centuries under the hegemonic rule of the Ilkhanids. Pope wrote in reference to this period, when old patterns were assimilated with new ones, that the Far East contributed "ideas and forms marked by a new naturalism and a new kind of elegance" that resulted in the juxtaposition of extremes—"the most relentless geometry is set beside the most exuberant floriation." He welcomed this revolutionary change:

> The Mongol shock just came at the moment when it was necessary to renew the whole substance of Iranian decoration if it were not to become moribund, for indeed the thirteenth century had done little more than mark time. Regeneration was effected, not by complete substitution, but by supplementation, so that continuity was not broken but rather sustained by fresh suggestions, and saved from lapsing by inertia.[45]

The Mongol-Ilkhanid synthesis continued to be elaborated between the late fourteenth and early sixteenth centuries by the Timurid and Turkmen dynasties. Geometric schemes in use since the eleventh century were transformed by the manipulation of their inherited grammar in terms of scale (successively fragmenting traditional motifs into

smaller elements or, conversely, magnifying them in an unprecedented manner), composition, color scheme, material, technique, placement, surprising juxtapositions, and contrasting combinations with curvilinear patterns (vegetal, floral, figural, or calligraphic) that expanded the set of designs to a virtually infinite number. Complex radial compositions displaced simpler ones based on rectilinear or diagonal grids, while designs generated by squared grids intended for transference to *bannā'ī* brick masonry took on a new prominence. Fourteenth-century advances in tiling techniques that culminated with the development of mosaic faience had widened the color scheme of tile revetments and facilitated the rendering of curvilinear patterns with greater precision. Eventually the linear strapwork interlaces of the Seljuq and Ilkhanid periods were dominated by the interlocking stars and polygons of the Topkapı scroll, which emphasize interpenetrating color fields more than linear interlacing. The scroll's strictly angular geometry also eliminated the curvilinear geometric interlaces of earlier periods that were no longer favored in Timurid-Turkmen tile work.

The incorporation of the geometric *girih* mode into a broader decorative vocabulary is documented in several Safavid texts that seem to be based on a Timurid-Turkmen classification of patterns. For example, the *Qānūn al-ṣuwar* (Canons of painting), written sometime between 1576 and 1602 by the Safavid court painter and librarian Sadiqi Bek (who had studied painting in the 1540s at the royal scriptorium of Tabriz under Muzaffar-ᶜAli), classifies genres of painting under two main categories, decorative and representational. The representational category is further subdivided into two types—figural painting (*ṣūratgarī*) and animal design (*janvār-sāzī*)—and the abstract art of decorators (*naqqāshī*) is described as consisting of seven fundamental modes (*aṣl,* lit., "base," or "root") with many variations (*farᶜ*, lit., "branch"):

> I speak here of the seven bases (*aṣl*) of decoral art [that is, of its seven basic patterns or design modes]. Yet it should be understood that there are many variations (*farᶜ*) as well. My own master [Muẓaffar-ᶜAlī], in guiding me, cited the basic patterns as follows: first come *islīmī* (the ivy-and-spiral [or vine-and-tendril] pattern) and *khaṭā'ī* (the Chinese floral pattern). You may then take as your third and fourth, *abr* [cloudlike or marbled pattern] and *vāq* [grotesque pattern featuring the head-bearing tree]. This leaves *nīlūfar* (the lotus) and *farangī* (the Frankish pattern) as your fifth and sixth. And with all these in mind, do not yet overlook the seventh, *band-i rūmī* (the Anatolian knot pattern). Once you have grasped the basic principles involved in these seven patterns, you should have no difficulty with the variations.[46]

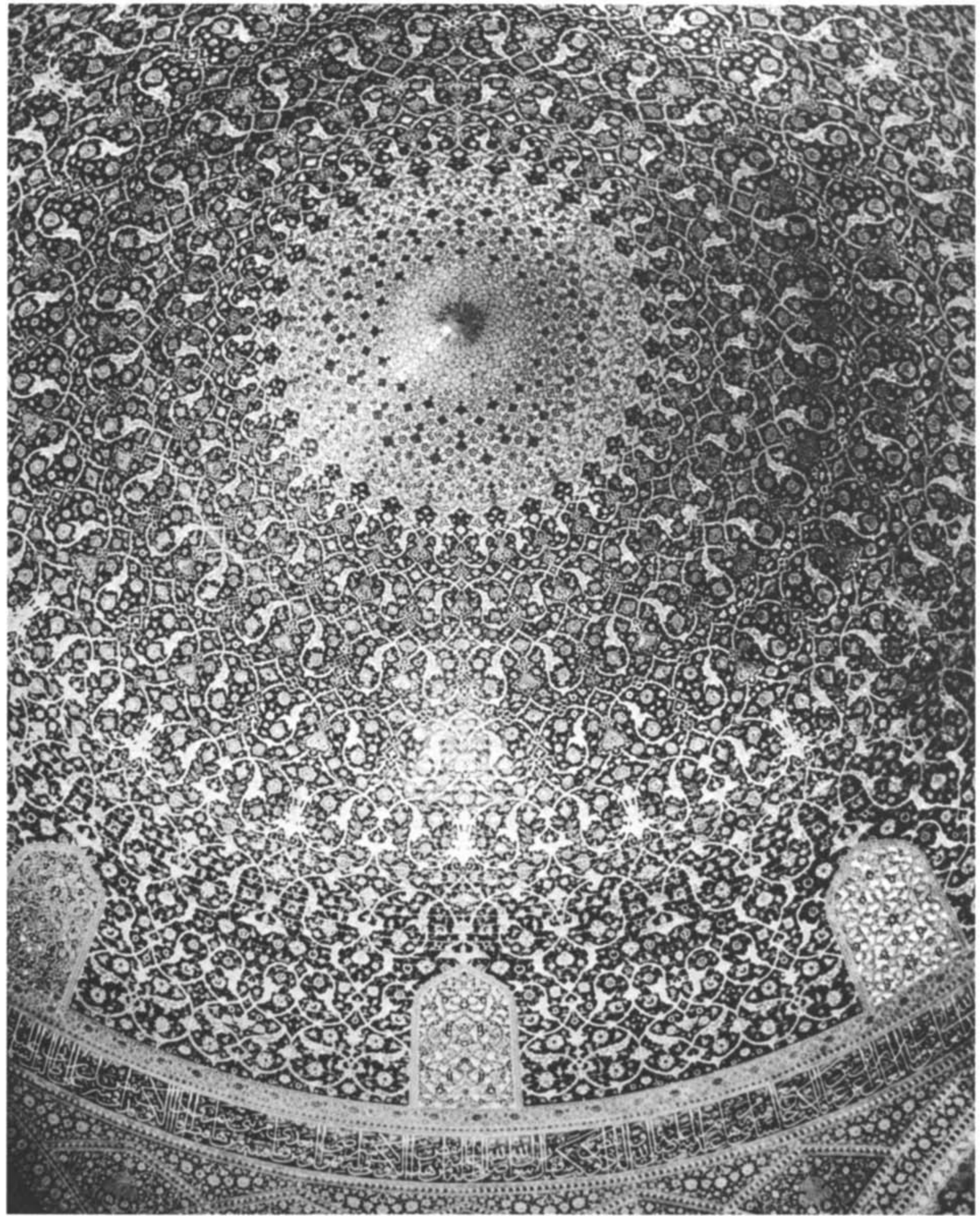
Another sixteenth-century Safavid author, Mir Sayyid-Ahmad Mashhadi, slightly modified this sevenfold classification of patterns used by decorators and illuminators, which echoed the sixfold classification of calligraphic modes developed in Abbasid Baghdad (to which a seventh category, *taᶜlīq*, was added in the post-Mongol period): "Just as in calligraphy the Six Pens are basic, in this craft there are seven fundamental modes (*aṣl*): *islāmī* [Islamic, a corruption of *islīmī*], *khaṭā'ī*, *farangī*, *fiṣālī*, *abr*, *vāq*, and *girih*."[47]

The *girih* or *band-i rūmī* was, then, only one of the available options in this broad repertory of design modes that could be used either alone or in various combinations with one another. Timurid and Turkmen illuminators, who made full use of this varied repertory in manuscript painting, also prepared patterns for the decorative revetments of specific building projects as we have already seen. These patterns complemented the purely geometric ones compiled by master builders in *girih* scrolls, contributing to the greater naturalism of the post-Mongol revetment aesthetic. Despite the wider variety of available patterns, however, architectural revetments and decorative vaulting continued to be dominated by geometric schemes well into the early sixteenth century.

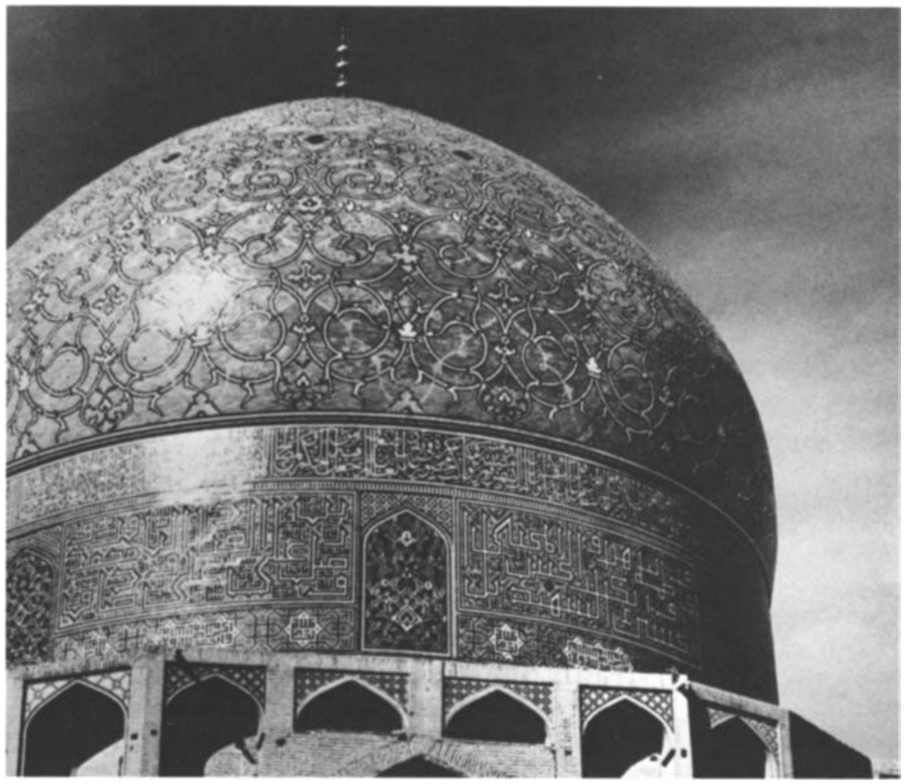
Although the Timurid-Turkmen dynasties, the Mamluks, and the Nasrids were able to sustain the innovative momentum of the *girih* mode by enlivening it with polychromy and intricate elaborations, the early modern Islamic empires that dominated the Muslim world between the sixteenth and eighteenth centuries seem to have felt that geometric patterning had reached a dead end.

The Ottomans, Safavids, and Mughals, who initially shared the international Timurid-Turkmen artistic heritage of the fifteenth-century eastern Islamic world, would eventually develop their own abstract idioms of architectural revetment representing differentiated dynastic tastes confined to relatively autonomous cultural zones. These distinctive decorative idioms no longer assigned geometry the privileged role it had enjoyed in architectural revetments from the late tenth through the early sixteenth century.

In the course of the sixteenth and seventeenth centuries geometric patterning was increasingly subordinated to the naturalistic floral idioms of the Ottomans and Mughals, on the one hand, and to the relatively more abstract curvilinear vegetal interlaces of the Safavids, on the other. As Pope noted, the Safavid period represented the "ultimate triumph of the floral style" in Iran: "The geometric style is now largely supplanted by a rich arabesque and floral ornament in which formal elements are happily combined with the seminaturalistic and with every intermediate degree of conventionalization" (figs. 94, 95).[48] The preference of the Twelver Shi^ci Safavids for floriated vegetal scrolls may well have been triggered by the specific association these forms had acquired at that time with the Prophet's son-in-law ᶜAli b. Abi Talib (d. 661), the revered first imam of the Shiᶜis. The calligrapher and painter Dost Muhammad's preface to the album of the Safavid prince Bahram Mirza in 1544 identified the vegetal arabesque as an invention of ᶜAli, who was "the first person to



94. Interior view of the tile-covered sanctuary dome, Masjid-i Shah, Isfahan, 1611–1638. Photo: Courtesy Fogg Fine Arts Films.



95. Exterior view of the tile-covered sanctuary dome, Masjid-i Shah, Isfahan, 1611–1638. Photo: Courtesy J. Powell, Rome.

adorn with painting and illumination the writing of the Word. . . . A few leaves (*barg*), known in the parlance of painters as *islāmī*, were invented by him."[49] The same tradition is repeated in Mir Sayyid-Ahmad's preface to another album, prepared in 1564–1565, where both the kufic script and the vegetal arabesque are associated with ᶜAli. It is explained that the latter invented the *islīmī* or *islāmī* mode upon being challenged in a competition by the infidel Chinese painters who designed a tray filled with naturalistic tulips and roses:

> When the king of sainthood [ᶜAli] saw
> that drawing, he seized the pen from them
> in inimitability.
> He drew a charming *islāmī* that astonished
> the people of Cathay.
> When that prototype fell into their hands,
> all other designs were lesser in their view.[50]

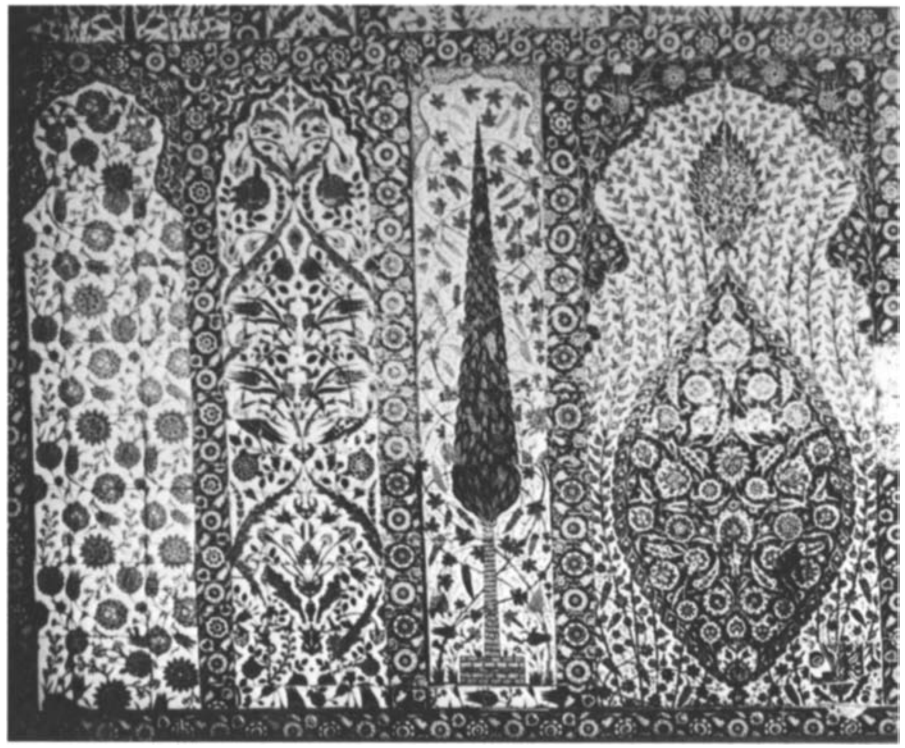
This apocryphal tradition of unknown origin demonstrates how abstract designs could be charged with specific contextual connotations that were not necessarily relevant throughout the Muslim world. Perhaps the Safavids (like the Fatimids before them) were not so keen on adopting the geometric *girih* because of its prominence in monuments associated with Sunni memories.

The Ottoman classical synthesis that emerged around the middle of the sixteenth century replaced the abstract Persianate decorative vocabulary of the early Ottoman period with a seminaturalistic floral idiom projecting a new, independent dynastic identity (fig. 96). The earlier geometric, vegetal, and chinoiserie motifs of the international Timurid-Turkmen style were not altogether abandoned, but they now became marginalized by designs including carnations, hyacinths, tulips, spring blossoms, and grapevines that recreated a garden atmosphere indoors. Predominantly curvilinear patterns accompanied by cursive calligraphy replaced angular geometry in the novel Iznik tile revetments, whose vividly colored, identifiable flowers with stems stood out in bright contrast against a white background as if to defy the figure-ground ambiguities so valued before. Although the Ottoman historian Mustafa Āli's late sixteenth-century biographical work on calligraphers and painters still referred to specialists of geometric patterning (*girih-bend*) among the illuminators of the Ottoman court, their specialization had fallen out of favor.[51] The *girih* continued to dominate the relatively more traditional media of joined woodwork, carved marble grilles, and the muqarnas, but it no longer enjoyed its earlier prominence.

The Mughals of India, who were the direct descendants of the Timurid dynasty, would also create their own nonfigural seminaturalistic floral idiom in the seventeenth century after having extensively used the *girih* in their earlier monuments (figs. 97, 98). The early Mughal style had been dominated by Timurid-type plaster carvings and tile revetments whose geometric patterns were sometimes translated into the local medium of tessellated stone mosaics (*khātim-bandī*). Eventually these traditional Persianate star-and-polygon com-

positions and their accompanying abstract vegetal interlaces were supplanted by more naturalistic stemmed flowers, partly inspired by European botanies and floral pattern books. Executed in white marble reliefs and in the Italianate *pietra dura* technique (*parchīn-kārī,* lit., "clenched work"), these seminaturalistic floral patterns were now accompanied by floriated vegetal interlaces displaying a Baroque flavor not unlike the arabesques in printed pattern books that the European goldsmiths and decorators who were employed in the Mughal court may have possessed. Of course, the geometric *girih* continued to live on in intricately carved stone window screens (*jali*), inlaid floors, plasterwork, and simplified muqarnas reliefs, but it certainly lost its former centrality.[52]

Geometric revetments, prone to monotony with their repetitive patterns governed by fixed formulas, were thus unable to survive the competition of new floral idioms invented in the early modern age. Their position of primacy remained unchallenged only in Uzbek Central Asia where the legitimizing prestige of the Timurid past assured their continued life, in the backward-looking architecture of the Maghrib, and in the eighteenth- and nineteenth-century monuments of Qajar Iran where geometric revetments enjoyed a revival from the late Safavid period onward. That revival would spread like an epidemic throughout the Muslim world in the late nineteenth and early twentieth centuries under the impact of Orientalist publications that identified the arabesque as a typical ingredient of Islamic architectural orna-



96. Sixteenth-century arched Iznik tile panels reused in the northwest gallery, Mosque of Sultan Ahmed I, Istanbul, 1609–1617. Photo: Courtesy Walter B. Denny.

97. *Pietra dura* inlay decoration on pillar base, Diwan-i Khass, Red Fort, Delhi, 1639–1648. Photo: Copyright Asian Art Archives of the University of Michigan.

98. Detail of floral low relief marble dado panel, Taj Mahal, Agra, 1631–1647. Photo: Copyright Asian Art Archives of the University of Michigan.

ment. The so-called geometric arabesque still continues to enjoy popularity in the revivalist contemporary architectures of such countries as Morocco and postrevolution Iran, where it is promoted as a fundamental aspect of traditional Islamic architecture.[53]

This brief outline helps us historicize the geometric *girih* mode, with its high point falling between the early eleventh and mid-thirteenth centuries and its last creative impulse manifested in the fourteenth- to early sixteenth-century monuments of Nasrid Spain, Mamluk Egypt, and the Timurid-Turkmen east. Though always present, geometry had not been in the forefront during the formative period of Islamic visual culture between the seventh and late tenth centuries, and it lost its innovative vigor in the post-sixteenth-century early modern era, despite its continued life in North Africa, Iran, and Central Asia. It did not constitute a timeless essence of Islamic visual culture, as most of the literature on the subject assumed, but was only one of many abstract decorative modes available. It was not independently invented in different places as the mysterious visual manifestation of a Muslim spiritual mentality; it was developed in a specific time and place and spread from there to other places. The Topkapı scroll, datable to the late fifteenth- or sixteenth-century Iranian world, therefore, represents a final regional culmination of the *girih,* which enjoyed a *longue durée* popularity in the medieval Islamic lands just before it became marginalized during the early modern era. The scroll's compilation coincided with the last burst of creativity that the late Gothic style experienced in contemporary Europe before its elaborate geometric fireworks were displaced by the numerical arithmetic approach of the Renaissance. In contrast to Europe, where the Renaissance largely swept away the Gothic architectural idiom, whose virtuoso geometric elaborations it rejected with a vengeance, the remnants of the *girih* mode continued to live on in various degrees of intensity in post-medieval Islamic visual culture, which did not experience a major paradigmatic shift comparable to the Renaissance. Nevertheless the predominantly floral visual idioms of the early modern Islamic empires seemed to signal the end of a medieval era and the beginning of a new one whose "protomodern" ethos calls for a detailed contextual analysis falling beyond the scope of this book.[54]

Neither the few remaining early medieval monuments nor the written texts provide much information about the original associations of the *girih* at the time of its inception, associations that appear to have shifted with changing collective memories over time and space. Later sources from the post-Mongol period provide a better sense of the range of meanings two- and three-dimensional geometric patterns could carry. The Safavid classifications of animate and inanimate modes of abstract design referred to above suggest that artistic creation, which could hardly aim to match the creation of God (*al-ṣāniᶜ*, "the divine artist"), took the different realms of nature as its ultimate models. Contrary to the widespread assumption that the so-called arabesque was the symbolic translation of the Islamic revelation into visual form, most primary sources limit the subject matter of art to the realms of nature, given the complete transcendence of God and of the message of the Koran. They often stress the parallelism between God's creation of the universe and the artist's modest creations that transform raw matter, a potentially dangerous parallelism addressed in several hadith that warn the painter about the futility of attempting to rival God through lifelike, naturalistic representations.[55]

It is written in the *Rasā'il* (Epistles) of the Brethren of Purity (Ikhwan al-Safa'), believed to have been composed by a group of authors with Shiᶜi leanings who were active in late tenth-century Buyid Baghdad, that skillful artisans should imitate God's creation to "assimilate His wisdom . . . as much as this is possible to man." The object of artistic creation, then, was "to imitate the science of the Creator" and to "reproduce the signs of His art in the natural production." In their introduction to the epistle on music the Brethren wrote, "In this Epistle music acts as a focus whose purpose is to explain and illuminate the wonders of creation, the phenomena of nature, and matters lying within the domain of human creation." Abdelhamid I. Sabra's observation that "the Brethren were aiming their teaching at the class of craftsmen and generally educated people" endows their writings with a special significance. The epistles of the Brethren of Purity, a fraternity-like society of Buyid government secretaries and

officials who preferred to remain anonymous, were not only studied by the philosopher and physician Ibn Sina (Avicenna, 980–1037) but also by such Sunni writers as al-Ghazali and even the strict Hanbali theologian Ibn Taymiyya. This shows that their teachings, to which we shall return in part 5, were not limited to Shiᶜi circles.[56]

A similar role is assigned to art in the Sunni scholar Muhammad al-Dawwani's (1424–1503) late fifteenth-century popular ethical treatise, adapted largely from earlier Shiᶜi texts including the ethics of the Mongol-Ilkhanid mathematician and astronomer Nasir al-Din al-Tusi (1210–1274). Written in the Aqqoyunlu court, this work brings us close to the milieu where the Topkapı scroll seems to have been compiled:

> Now nature is superior to art, for it is derived from the highest of sources, without the intervention of human judgment; whereas art proceeds solely from such intervention. Nature then is the pedagogue and preceptor of art; and as the perfection of things secondary lies in their resemblance to originals, the perfection of art must lie in its resemblance to nature, which resemblance it may attain by anticipating or postponing means, and arranging them generally in their appropriate course: so that that perfection which, under Providence, is effected by the agency of nature, may be accomplished by art under the guidance of human will; and this with a peculiar virtue belonging only to art.[57]

No matter how abstract, then, artistic creation had to be modeled on the phenomena of nature, a concept repeated in a wide variety of sources. For example, Mir Sayyid-Ahmad's preface to the Safavid album of paintings and calligraphy mentioned above described artists who specialized in the seven basic modes of abstract illumination, including the *girih*, as deriving their prototypes from nature, the creation of the divine artist:

> What marvelous wielders of pens of sorcery who bestow life with magic-making pens!
> Latched onto every created thing, they reproduce the likeness of every thing.
> They follow God's craft from the compass of the spheres to the surface of the earth.
> With their gazes fixed on creation, they take an image from every prototype.[58]

Just as painters derived abstract modes of illumination from the prototypes of nature, architects are often described as imitating the order of the cosmos in their buildings. The late sixteenth- and early seventeenth-century biographies of the Ottoman architects Sinan and Mehmed, for example, start by comparing God to an architect, an image widely used in the Islamic world, Byzantium, and the Latin West alike. Sinan's autobiography composed by the poet-painter Saᶜi begins with a section that thanks the divine creator (*ṣāniᶜ*) who laid the foundations of the seven stories, built the nine-arched dome of heaven, and created the palace (*ḳaṣr*) of the body of Adam "without ruler or compass" simply through the command "Be!" The same text draws an implicit parallel between the cosmos and Sinan's monumental mosques crowned by domes of heaven, a parallel that also informed the architectonic structure and decorative programs of earlier Byzantine churches.[59]

Mehmed's biography composed by Caᶜfer Efendi, *Risāle-i Miᶜmāriyye* (Treatise on architecture), begins with a similar dedication: "Let there be endless thanks and numberless praises of that God who created men, who opened the door of the palace of wisdom and who in accordance with the command 'Be! And it is,' . . . created . . . this great workshop, perfect in form as an ideal of the mind, containing and comprising seven lower levels and seven upper levels." A detailed description of the cosmos is followed by praise of the divine architect's wondrous creation: "What is this vault of heaven, and what is this surface of the world? What is this lofty arch, and what is this lofty pavilion? How is it that such an edifice was artfully made without drawings [plans] and without geometry and without a [three-dimensional] model?"[60] The Sultan Ahmed mosque (1609–1617) designed by Mehmed is described in similar terms, its dome compared to the illuminated vault of heaven, its mihrab to rainbows, and its arched galleries to mountains, indicating that its microcosmic struc-

ture was considered replete with allusions to nature.

Given the "naturalistic" references encoded in buildings, their surfaces—covered with two- and three-dimensional *girih* patterns dominated by the geometry of stars and polygons—could easily trigger cosmological associations. As Bourgoin and others noted, polygonal interlaces seemed to evoke the crystalline harmonic structure of a mathematically ordered inanimate material world. Among geometric patterns those featuring stars resonated with heavenly allusions. The underlying orbitlike concentric grids of stellate *girih* patterns punctuate the surfaces they cover with pulsating nodal rotocenters marked by stars, whose equidistant radii emanating like light rays create an effect reminiscent of the emanation of light in a starry sky. The extended lines of multiple star centers interlink to form polygons and subsidiary star clusters charged with a vaguely representational character. Instead of being precise representations of stars and heavenly orbits as they would appear in contemporary astronomical treatises, however, these *girih*s are simply geometric abstractions working on the level of a suggestive analogy or metaphor. They recall the Dutch artist Piet Mondrian's (1872–1944) speculation in a letter about the multiplicity of stars in the night sky and the formal relations that lines between these stars could make manifest: "The starry sky shows us innumerable points not all equally emphasized: one star twinkles more than another; and now again these unequal light values engender forms."[61]

The heavenly associations of stellate *girih* patterns are captured in some textual descriptions; for example, in 1544 Dost Muhammad referred to the gilded geometric interlaces of a Safavid illuminator as "made from the rays of shooting stars" that create "abodes of burnished gold in his sunbursts."[62] The names assigned to stellate *girih*s by contemporary Iranian master builders are also suggestive; they refer to compositions with twelve- and six-pointed stars as "twelve and six heavens" (*duwāzdah wa shash gardūn*) or to those with twelve- and eight-pointed stars as "twelve and eight heavens" (*duwāzdah wa hasht gardūn*). The conchlike fluted semidomes or domelets from which most star-studded muqarnas tiers are radially generated like rays cascading from a central source of light are referred to as sun figures (*shamsa*) by the same builders (see figs. 67–69).[63] That two- and three-dimensional *girih* patterns could also be charged with specific heavenly references through accompanying poetic or Koranic inscriptions is demonstrated by several examples in the Alhambra. Here the stellate plaster muqarnas dome of the fourteenth-century Hall of Two Sisters and the wooden *artesonado* vault of the neighboring Hall of Ambassadors (also built in the fourteenth century), composed of seven tiers of six- and eight-pointed stars interlocking with polygons, can both be identified as analogues to the heavens by means of their carefully chosen inscriptions. This confirms the kinship between spatial and planar geometric patterns that are juxtaposed in *girih* scrolls.

It has been recognized that the Alhambra's *artesonado* vault was meant to allude to the seven heavens referred to in an accompanying Koranic inscription: "Blessed is He in whose hand is the Kingdom. . . . Who created seven heavens one upon another. Thou seest not in the creation of the All-Merciful any imperfection. Return thy gaze; seest thou any fissure? Then return thy gaze again, and again, and thy gaze comes back to thee dazzled, aweary" (67: 1–4).[64] The layering of the vault in superimposed tiers and the fitting together without any gaps of congruent stars and polygons can thus be identified as a metaphor for the wondrous design of the heavens created by the wisdom of God. This Koranic quotation implies that God's creation is similar to that of a patternmaker concerned with the problem of tightly fitting together harmoniously proportioned congruent shapes and closely packed geometric solids without any gaps. The bedazzlement of the weary beholder, unable to decipher the ingenious underlying order of the divinely created universe, parallels the aesthetic effect of *girih* patterns whose interlocking stars and polygons continuously seem to metamorphose into one another without revealing their hidden geometry.

Grabar interpreted the muqarnas dome of the Hall of Two Sisters as an image of the revolving vault of heaven on the basis of the Andalusian poet Ibn Zamrak's (1333–1393) Arabic poem inscribed around its base, which is pierced with windows creating an interplay of light and shade, diffused in subtle gradations by muqarnas shells arranged in a

multitiered stellate composition.[65] He wrote, "It is as though the cupola was understood as a rotating one, reflecting the daily cycle of light and darkness and the changing positions of constellations." The relevant parts of the poem read:

> In here is a cupola which by its height
> becomes lost from sight; beauty in it
> appears both concealed and visible.
> The constellation of Gemini extends a
> ready hand [to help it] and the full moon
> of the heavens draws near to whisper
> secretly to it.
> And the bright stars would like to establish themselves firmly in it rather than
> to continue wandering about in the
> vault of the sky.
> . . . .
> And how many arches rise up in its vault
> supported by columns which at night are
> embellished by light!
> You would think that they are heavenly
> spheres whose orbits revolve, overshadowing the pillar of dawn when it barely
> begins to appear after having passed
> through the sky.
> . . . .
> When they are illuminated by the rays of
> the sun you would think that they are
> made of pearls by reason of the quantity
> of celestial bodies in them.[66]

These references to light suggest that the superimposed tiers of stellate muqarnas vaults could be read as abstract analogues for the multilayered heavens studded with glittering celestial bodies and imbued with brilliant light. This visual analogy frequently was heightened by color schemes dominated by blues and gold and by the piercing of muqarnas vaults with windows along their base or with round openings on each tier, fitted with glass bulbs from which real rays of light poured in. That the association with light was relatively common is suggested in a description of the sixteenth-century Ibrahim Pasha Palace overlooking the Hippodrome in Istanbul as touching the stalactited heavenly spheres (*çarḫ-i muḳarnas*); its vaults were so elaborately decorated that the sun's rays would not suffice for the *girih*s of their muqarnases (*muḳarnaslarınuñ girihlerine żamīr-i āfitāb yitişmez*).[67]

Given the Koranic association of light with God expressed in the Light Verse, the radiating rays of two- and three-dimensional *girih*s that transform the surfaces of buildings into vibrations of light and color (a function of light) were also open to a wide range of religious resonances. It is, therefore, not surprising that the elaborate muqarnas portal of the madrasa complex of Sultan Hasan in Cairo quotes the Light Verse (24: 36–37). The muqarnas hood may have been a metaphor for the emanation of light in the universe created by God, the artistically representable inanimate realm of nature and natural phenomena.

The Neoplatonic doctrine of emanation, which regarded the origin of the universe as an eternal radiation of light from a first principle (the One, or pure light), had become a cornerstone of Islamic philosophical thought in the tenth and early eleventh centuries, particularly in Muᶜtazili and Shiᶜi circles. Majid Fakhry pointed out that the emanationist worldview "to which the Muslim philosophers adhered almost without exception" was developed in the writings of such thinkers as al-Farabi, Ibn Sina, and the Brethren of Purity, becoming further elaborated in Shihab al-Din al-Suhrawardi's mystical philosophy of illumination. The heterodox implications of this view upholding the eternity of the material world would be attacked by the polemicists of the Sunni revival, who restored the Koranic concept of a universe created in time without any intermediaries by an omnipotent and omnipresent God whose knowledge extends to "the smallest particle in heaven or on earth" (34: 3).[68]

Nevertheless, just as the Muᶜtazili atomistic cosmology would be appropriated by the Ashᶜari school in modified form, reformulated themes of Neoplatonic cosmology and metaphysics crept into Sufism. Although al-Ghazali criticized such Muslim philosophers as al-Farabi and Ibn Sina who wrote about the spontaneous generation of the universe from a pure light source, he did adopt their metaphor of light in his *Mishkāt al-Anwār* (Niche of lights), a mystical interpretation of the Light Verse as an allegorical reference to the light of divine revelation, reflecting an amalgam of Neoplatonic and Sufi doctrines. In

doing so, he shifted the philosopher's emphasis on reason to an experiential form of intuitive illumination in the quest for divine knowledge.[69] His new Sunni orthodox synthesis therefore involved a selective "process of assimilation" that blurred the lines between traditionist theology, philosophy, and mysticism, ending in a complete "naturalization" of the imported Greek sciences in Muslim soil.[70]

The persisting echoes of Neoplatonic light imagery—the epitome of clarity, brilliance, purity, and detachment from material defilement—may have informed the pre-Mongol associations of the *girih* whose continuing life in the post-Mongol eastern Islamic world was nourished by an increasing receptiveness to all types of Sufism, ranging from orthodox to unorthodox. The long-lasting popularity of the *girih* in this middle period of Islam (a term conceived by Marshall Hodgson, who subdivides it into the early middle period [950–1250] and later middle period [1250–1500]) seems to signal a preoccupation with the sublime aesthetics of light and proportion, which was also shared in the medieval Christian world as we shall see in part 5.

Even though the specific associations of two- and three-dimensional geometric patterns during the Sunni revival do not seem to have been articulated in contemporary written sources, these patterns were dominated by stellate compositions from the very beginning. In Samarra the Imam Dur's early stucco muqarnas dome (circa 1085), for example, forms a multitiered eight-pointed star culminating in a conch with eight sectors. Stellate compositions also characterize the twelfth-century conical muqarnas domes crowning the so-called tomb of Zubayda in Baghdad and Nur al-Din's madrasa and hospital complexes in Damascus. The twelfth-century flat wooden muqarnas vault of the Capella Palatina in Norman Palermo, on the other hand, features prominent eight-pointed stars alternating with eight-partite conches, embellished with figural personifications of the planets, zodiacal signs, and constellations. It was likened in a twelfth-century homily by the monk Philagathos to "the sky at night when a host of stars twinkle down through the clear sky."[71] Philagathos described this muqarnas vault as follows: "You do not tire of contemplating the roof, a cause of wonder and marvel to those who see it or hear about it. Embellished as it is with delicate carvings, which are executed as differently shaped coffers and shining with gold from all sides, it imitates the clear sky of heaven, illuminated by the choir of stars."[72] This antinaturalistic, abstract imitation of the night sky bearing no resemblance to the actual structure of the heavens illustrated in contemporary astronomical texts was once again conceived as a loosely interpreted analogy, rather than a precisely worked out symbolic representation.

The Seljuq historian Ibn Bibi described the domed halls of the early thirteenth-century Kubadabad Palace in Anatolia in similar terms, referring to "their vaulted domes that rivaled the muqarnas of the highest heavens," which out of jealousy for the turquoise and azure decorations of these gilded palatial domes turned their own turquoise-colored appearance into indigo blue and saffron yellow.[73] The term *muqarnas* is also used in the Persian poetry of Nizami of Ganja (1140–1202) and Hafiz (d. 1390) as an attribute of the heavens, built in layers (*ṭabaqa*) inlaid with glistening stars. Following the same tradition the fifteenth-century Timurid historian Sharaf al-Din ᶜAli Yazdi compared the arched portals of a palace in the Dilgusha Garden at Samarqand to "the stalactited roof [*ṭāq-i muqarnaṣ*] of the celestial sphere,"[74] just as the contemporary historians ᶜAbd al-Razzaq al-Samarqandi, Dawlatshah, and Khwandamir consistently referred to the sky as a "stalactited vault or roof" (*ṭāq-i muqarnaṣ, saqf-i muqarnaṣ*).[75]

This popular analogy must have accentuated the implicit heavenly associations of muqarnas vaults, also expressed in the inscriptions of several Timurid monuments. A now-lost muqarnas-domed pavilion (*gunbād-i muqarnas*) in Yazd, for instance, was inscribed with a poem by Saᶜdi (d. 1292) that praised God as the creator (*ṣāniᶜ*) of the universe, the sun, the moon, and the stars.[76] The fact that this famous Persian poet was a student of ᶜUmar al-Suhrawardi, the promoter of orthodox Sufism at the late Abbasid caliph al-Nasir's court, brings us closer to the Baghdadi milieu where the geometric mode reached its full-fledged expression just before the Mongol invasion. The heavenly metaphor must have become more explicit with the increasing popularity of the radially symmetrical Shirazi type of stellate muqarnas that dominates the vault projections

of the Topkapı and Tashkent scrolls. These star-studded muqarnas vault projections do recall the Timurid astronomer-mathematician al-Kashi's praise of the heavens: "Thanks and [praise] and incomparable glory is due to the / Power [the Creator] who has inlaid the layers of the heavens with glistening pearls, with shooting [stars], and glittering jewels / the planets and the fixed [stars]."[77]

Some extant inscriptions on Timurid-Turkmen monuments support the cosmological associations of muqarnas vaults that indirectly seemed to glorify the divine creator by inviting the gaze to contemplate the wonders of creation. For example, the muqarnas-hooded entrance portal of the Shad-i Mulk Aqa mausoleum (1371–1383) in the Shah-i Zinda complex in Samarqand carries the following inscription: "This roof full of muqarnas [*saqf-i pur muqarnaṣ*] and this gilded vault [*ṭāq-i zarnigār*] / Are an expression of beauty [*zayn*], / Calling to mind that all of the decor and art you see in this world / Is by favor of the Creator, the Omnipotent." This quatrain, which attributes the beauty of the cosmos to its divine creator, is followed by two others referring to death, burial, and the transience of life in the material world. They end with the declaration: "Do not expect fulfillment in this transitory world / While the arch and the summit stand, such will be the case," an allusion to the cosmos, echoing the references to architecture made in the first quatrain.[78]

The increasing emphasis of Timurid monumental inscriptions on the transitoriness of life on earth (see cat. no. 51a), together with references to God's absolute power and wisdom as manifested in the divine creation, reflect the mystical ethos of this period, characterized by the rising status of Sufi poetry in the fourteenth and fifteenth centuries.[79] This ethos is best captured in the deeply mystical poetry of ᶜAbd al-Rahman Jami (1414–1492), the greatest of all Timurid poets, whose two disciples Mir ᶜAli Shir Nawa'i (1441–1501) and Sultan Husayn Bayqara (1438–1507) were among the foremost patrons of late Timurid art and architecture in Herat.[80] Contemporary biographies of poets, such as those by Nawa'i and Dawlatshah, testify to the widespread popularity of Persian poetry and Sufism among different strata of late Timurid society, ranging from professional poets and the ruling elite to soldiers, the common people, and the bazaar folk. The increasing use of inscriptions quoting mystical Persian poetry on Timurid buildings seems to have addressed this growing literate population, which made Dawlatshah complain, "Wherever you listen, you hear the murmur of a poet, and wherever you look, you see a Latifi or a Zarifi or a Naziri."[81]

The growing trend in Timurid-Turkmen architecture to complement Arabic epigraphy with Persian poetry highlighted a new kind of dialogue between visual and verbal signs. The way in which poetry could enrich the communicative potential of accompanying abstract patterns in architectural revetments is captured by an inscription on the entrance portal of the Darb-i Imam in Isfahan. This portal, which features a tile mosaic muqarnas hood combined with stellate arch-net squinches, is flanked by mosaic tile relief panels of interlocking stars and polygons in two different layers (see fig. 63) that recall similar designs included in the Topkapı scroll (see cat. nos. 38, 49). Its poetic inscription reads: "There is a metaphor for this in the revolution of the dome of the heavens. . . . See, with the eye of understanding, how that [building] whose ivan passed above the seventh heaven [Saturn], fell to the earth."[82] This inscription once again highlights the parallelism between the multi-tiered revolving heavens and the vaulted building, charging its abstract revetments with heavenly allusions displayed for the insightful gaze. The widespread use in the Iranian world of such poetic inscriptions, permeated with cosmic themes, can be deduced from the fifteenth-century local histories of Yazd where they are quoted and from the extant Persian foundation inscription of the Çinili Köşk at the Topkapı Palace in Istanbul, which was built in the Timurid-Turkmen idiom.[83]

Timurid-Turkmen buildings completely covered with polychromatic geometric patterns, angular and cursive inscriptions, as well as vegetal and floral motifs, could induce in receptive observer-users a contemplative mood through their endless repetition of Arabic pious phrases, accompanied by longer poetic inscriptions in Persian. Square kufic pious aphorisms, most of them in Arabic, abound in the Topkapı scroll, where they are juxtaposed with *girih* patterns for *bannā'ī* brick masonry. These phrases, so prominent in Timurid architectural revetments, supplied abstract pat-

terns with extra cues. Well-known Koranic phrases such as "Praise be to God!," "God is Great!," "There is no god but God," or the repeated names of *Allāh, Muḥammad,* and *ʿAlī* created a visually harmonious setting full of religious reminders (see cat. nos. 1, 40, 41, 43, 45, 51b–c, 51e–g, 51i, 68b, 69a, 71, 72a, 75–77, 91). Their visual repetition has been compared with verbal repetitions known in Sufi practice as *dhikr* (lit., "remembrance," or "commemoration").[84] This ritual repetition of a litany, designed to intensify mystical meditation, was seen as a method of reminding oneself of God's greatness and the marvels of the divine creation. The contemplation of abstract patterns modeled on nature could be channeled into specific directions by such inscriptions capturing the Sufi sensibilities of the Timurid-Turkmen world.

Like the Alhambra's polychromatic revetments that endlessly repeat the Nasrid heraldic motto, "There is no Conqueror but God," the formulaic pious aphorisms prominently displayed on the facades of Timurid buildings imbued abstract patterns with specific moods. In the Alhambra repeated short phrases readable in a furtive "monoptic" Glance were also accompanied by longer poems in Arabic requiring the concentrated effort of the Gaze. As Jones wrote, the Alhambra's "Moresque ornaments" that addressed themselves "to the eye by their outward beauty, at once excited the intellect by the difficulties of deciphering their curious and complex involutions, and delighted the imagination when read, by the beauty of the sentiments they expressed and the music of their composition." He added that these ornaments could contain different subjective meanings:

> To the artist and those provided with a mind to estimate the value of the beauty to which they gave a life they repeated, *Look and learn.* To the people they proclaimed the might, majesty, and good deeds of the king. To the king himself they never ceased declaring that there was none powerful but God, that He alone was conqueror, and that to Him alone was for ever due praise and glory.[85]

Through the added "pointers" of inscriptions and other contextual factors, the otherwise ambiguous two- and three-dimensional patterns of the *girih* could trigger specific associations, but it is highly unlikely that these patterns were assigned with fixed iconographic meanings wherever or whenever they appeared. Nowhere in the written primary sources can one find any evidence for the a priori claim that geometric patterns were universally understood as symbols of the concept of *tawḥīd* that endowed multiplicity with unity. These evocative patterns could trigger religious, metaphysical, or mystical speculations, but they were by no means symbolic or iconic "representations" of them. Such redundant and deliberately ambiguous polysemous signs were susceptible to a multiplicity of subjective interpretations and a wealth of resonances not limited to religion. They could also evoke a sense of beauty, wonder, power, and wealth, depending on the context and the inclinations of the viewer. Like the classical orders, two- and three-dimensional *girih* patterns could support multiple connotations, even contradictory ones, though their slightly representational character, betrayed by the consistent use of stars, was conducive to particular kinds of resonances.

It was this flexibility of the *girih* as a multilayered contextual sign system that assured its long life, a flexibility in keeping with the much-noted ambiguity of Islamic patterns based on a looser associational system of signification rather than on a rigidly codified iconographic one. Geometric patterns, sometimes charged with specific meanings through accompanying inscriptions or other pointers, thus occupied an intermediary zone between the "decorative" and the "symbolic." This rescues them from being relegated into the realm of meaningless decoration, merely aimed to please or to satisfy the assumed horror vacui of the Muslim subject. It also justifies a semiotic reading sensitive to the varying contextual factors overlooked by essentialist symbolic interpretations.

To summarize, then, the geographical, chronological, and semantic horizons of the *girih* were much more flexible than assumed in the secondary literature that attributed timeless religious, mystical, or cosmological meanings to the arabesque irrespective of context. Since the *girih*'s associations during the age of Sunni revival are less documented than the ones it came to acquire in later periods, we have attempted to deduce them by turning to the cultural context of late Abbasid

Baghdad where this mode of design seems to have originated. The striking parallelism between the geometric mode and the ethos of the Sunni revival, however, goes beyond just an assumed zeitgeist. More than simply a collective worldview or weltanschauung informing an intrinsic analogy between the arts, religion, and philosophy, comparable to the one posited in Erwin Panofsky's *Gothic Architecture and Scholasticism*, 1951, it was the concrete circumstances of artistic production in the courts of late Abbasid Baghdad that contributed to the initial formulation of the *girih* mode.

The codification in Baghdad of the canonical Arabic scripts according to a geometric system of proportioning was not only related to theological and political controversies about the nature of the Koran but also to the popularization of the mathematical sciences in that city. During the tenth and eleventh centuries the professional mathematicians of the Baghdad school disseminated theoretical advances in their field by simplified practical manuals addressing the application of mathematics to everyday needs. Just as the trickling down of the speculations of philosophers into popular mysticism would have made them more accessible to the arts and crafts, it was the popularization of the mathematical sciences that facilitated the application of geometry to design.

The mathematician and astronomer Abu al-Wafa' al-Buzjani (940–998), who had emigrated from his hometown in Nishapur to Baghdad in 959–960, was one of the scholars involved in this systematic process of popularization that continued well into the eleventh century. During his more than two decades of political experience in Buyid Baghdad this celebrated mathematician had developed close connections with administrators, secretaries, land surveyors, merchants, architects, artisans, and calligraphers whose special needs he addressed in several practice-oriented manuals and in theoretical and practical mathematics courses that had many auditors.[86] One of these practical manuals, entitled *Kitāb fīmā yaḥtāju ilayhi al-ṣāni*ᶜ *min a*ᶜ*māl al-handasa* (About that which the artisan needs to know of geometric constructions) is thought by Woepcke to have been compiled from class notes by a pupil of al-Buzjani. This manual, to which I will return in part 4, seems to have been based on applied geometry exercises solved in class meetings. Its text refers to sessions that al-Buzjani presided over where professional geometer-engineers and artisans would propose differing solutions to given problems. The manual addressed the perception that practitioners in various fields of design required better grounding in the methods of constructive geometry.[87]

A similar interaction between theoreticians and practitioners is also documented in the Abbasid court's royal ateliers just before Buyid rule was established in Baghdad. It is reported that when the caliph al-Muᶜtadid (r. 892–902) built his palace at Baghdad in 901, he designated an area for the teaching of all the crafts (*kull ṣināᶜat*) and the various branches of theoretical and technical sciences (*al-*ᶜ*ulūm al-naẓarīya wa al-*ᶜ*amalīya*), providing it with generous financial support.[88] This area, recalling the court workshops and scriptoria (*kitābkhāna* or *kutubkhāna*) of the post-Mongol period, appears to have had a wider interdisciplinary horizon capable of encouraging a lively dialogue between theory and praxis. It must have facilitated a direct exchange between intellectual and artistic production in the very locus of the court where religiophilosophical debates were being formulated into official doctrines. The spatial proximity of court-sponsored activities in different fields explains the intersection of aesthetic and extra-aesthetic discourses that resulted in artistic practices directly responding to dominant ideologies, possibly under the guidance of erudite advisers. From the Baghdadi court milieu, which encouraged the cross-fertilization of ideas and practices across various disciplines, the *girih* easily could have spread to neighboring courts whose local rulers acknowledged the suzerainty of the Abbasid caliphs. It continued to be elaborated and further developed into regional dialects in these diverse courts, nourished by the availability of practical geometry manuals that left an unmistakable stamp on the geometric repertory and design methods of *girih* scrolls.

NOTES TO PART 3

1. Herzfeld 1942, 40.
2. Riegl 1893 (1992), 298.
3. Ibid., 281.
4. For Samarra, see Sarre and Herzfeld 1911–1920; Herzfeld 1912; idem 1916; idem 1923; idem 1927; and idem 1948.
5. Pope and Ackerman 1938–1939, 3: 2743–44.
6. Ibid., 3: 2753.
7. For the beveled style, see Herzfeld 1923; Creswell 1932–1940, 2: 286–88; Dimand 1937; idem 1952; Ettinghausen 1952; Ettinghausen and Grabar 1987, 101–5; and Allen 1988, 1–15, 50–57. Kühnel stated that the arabesque was already formed in the ninth century and became more fully developed under the Seljuqs, Fatimids, and the Moors; see Kühnel 1977, 561. Marçais dated the appearance of polygonal arabesques to the tenth century, observing that they particularly flourished in the twelfth and thirteenth centuries when they spread from the east to Andalusia; see Marçais 1947, 49. Allen dated the formation of the true arabesque to the tenth and eleventh centuries, attributing its development to a sort of evolutionary drift of forms away from their late antique sources. This resulted in the creation of self-referential abstract patterns that reflect "the pursuit of visually complex ornament"; see Allen 1988, 6, 54.
8. For Qairawan, see Creswell 1989, 324–26. The woodwork from Takrit is discussed in Dimand 1937, 293.
9. Strzygowski 1917, 88–98; Diez 1917, 68; Herzfeld 1923; Ettinghausen 1952. For the Samarran beveled style and further bibliography, see part 3, n. 7, above. The Raqqa capitals are illustrated in Allen 1988, figs. 33, 34.
10. For the Muᶜtazila school and its cosmological theories, which were by no means monolithic, see Gimaret 1993; Fakhry 1983, 37–42; and Van Ess 1992, 31–428. Most of the writings of the Muᶜtazila school have disappeared. Ibn al-Nadim listed a large number of Muᶜtazili works on the subjects of atom and accident that capture the preoccupation with developing a new atomistic cosmology; see Ibn al-Nadīm 1970, 1: 380–435.
11. Massignon 1921.
12. For an interpretation of the Umayyad Dome of the Rock as a representation of God's throne, see a forthcoming study by Julian Raby, "The Dome of the Rock and the Last Day," in Jeremy Johns, ed., *Bayt al-Maqdis: ᶜAbd al-Malik's Jerusalem*, vol. 9, bk. 2 of *Oxford Studies in Islamic Art* (New York: Oxford Univ. Press). The Umayyad attempt to physically represent God's throne as it would appear during the Last Judgment in Jerusalem must have been regarded as anathema by the Abbasids, whose theologians were engaged in a heated debate about the nature of God's throne as a metaphor because of its anthropomorphic implications. The increasing preference in the Abbasid period for abstraction over naturalistic representation is captured in several hadith, such as the one transmitted by Ibn ᶜAbbas (the grandfather of the Abbasids) that urges the painter to "decapitate animals so that they do not seem to be alive and try to make them look like flowers" and others warning that whoever draws lifelike figures competing with God's creation will have to breathe life into them in hell. Ibn ᶜAbbas's hadith is quoted in relation to the beveled Samarran style in Grabar 1983c, 110. For relevant hadith, see al-Faruqi 1989, 262–63; and Van Reenen 1990. See also Griffith 1985; and Hodgson 1964.
13. al-Masᶜūdī 1989, 239.
14. Ibid., 306. Al-Qadir's policies are summarized in Sourdel 1978; see also Tabbaa 1991. For the Sunni revival, see Makdisi 1973.
15. Watt 1960; al-Bāqillānī 1957; al-Ashᶜarī 1953.
16. Ibn Khaldūn 1967, 3: 52.
17. For religion in the Seljuq and Mongol periods, see Bausani 1968. For the Maturidi school, see Madelung 1991.
18. For the "brick style," see Ettinghausen and Grabar 1987, 217–24; Oleg Grabar 1992, 142–48; and Mülayim 1982. The geometric patterns of the Kharraqan tomb towers are analyzed in Stronach and Young 1966. For the geometry and early chronology of star patterns, see Lee 1987.
19. Herzfeld 1942, 40; Diez 1917; Aslanapa 1971; Mülayim 1982; Pope and Ackerman 1938–1939, 3: 3745. The earliest surviving cursive monumental inscriptions, often juxtaposed with geometric and vegetal arabesques, are also from the easternmost regions of the Islamic world, where they appeared toward the end of the reign of the Ghaznavid ruler Mahmud (998–1030) and continued to be used in later Ghaznavid and Ghurid inscriptions. Tabbaa wrote: "In the absence of any supporting evidence, it is difficult to say whether cursive official inscriptions were used by ᶜAbbāsid caliphs in the first half of the eleventh century. But in view of the large-scale destruction of most early and medieval monuments in Baghdad, it is possible that such inscriptions once existed and may have provided a model for the Ghaznevid development"; see Tabbaa 1994, 128.
20. Allen 1988, 72–75. For late Abbasid structures in Baghdad, see Strika and Khalil 1987, esp. pp. 14–15, 42–45, 66–74. The Mustansiriya and the so-called Abbasid Palace in the citadel of Baghdad are analyzed in Schmid 1980.
21. For a description and photograph of the Aqsa minbar before it was burned by a Christian fanatic, see Tabbaa 1986, 230–35. Tabbaa interpreted this minbar as an ex-voto for the impending capture of Jerusalem.
22. Star-and-polygon patterns are seen in such rare examples as the portable wooden mihrabs of the shrines (*mashhad*) of Sayyida Nafisa (made in the 1130s or 1140s) and Sayyida Ruqayya (1154–1160) in Cairo and the wooden minbars of the *mashhad* of al-Husayn at Ascalon (1091–1192) and of the Amri mosque at Qus (1155–1156). For Fatimid woodwork and the introduction of the muqarnas in Egypt, see Lamm 1936; and Bloom 1988. The Iraqi origin of the Damascene buildings is argued in Tabbaa 1985.
23. For the Anatolian monuments, see Ögel 1963; Aslanapa 1971; and Mülayim 1982.
24. Ibn Khaldūn 1967, 3: 54.
25. For the Almohads, see Shatzmiller 1993; Brunschvig 1958; Huici Miranda 1956–1957; and Le Tourneau 1969. Bernard of Clairvaux's *Apologia* is analyzed in Rudolph 1990a.
26. Ibn Jubayr 1907, 253. For this minbar, later moved to the Aqsa mosque, see part 3, n. 21, above.
27. Grabar 1978, 182, 195–201, 205. The Nasrid dynasty reestablished ties with the Abbasid caliphs, whom they recognized as the spiritual heads of Sunni Islam like the Almoravids before them.
28. Paccard 1980, 1: 145, 154. For the Persian terminology, see Lentz and Lowry 1989, 169.
29. Star-and-polygon patterns that dominated Anatolian Seljuq architectural revetments in the first half of the thirteenth century were replaced with a predominantly vegetal mode of ornament after the Mongol invasion of Anatolia in 1243; see Ögel 1963; and Mülayim 1982. Chinese motifs in post-Mongol Iranian and Turkish art are analyzed in Rawson 1984, 145–98.
30. Riegl 1893 (1992), 299, 305; Kühnel 1977, 12; Herzfeld 1987, 367.
31. Kühnel 1977, 11–12.
32. Ibn Rushd 1954, 13; al-Ashᶜarī 1953, 12–13. The Harranean astronomer al-Battani (d. 929) wrote that astronomy could lead people to reflect on the unity, majesty, wisdom, and power of God and quoted verses from the Koran to support this view. Similarly, Ibn Rusta's universal geography, circa 903–913, described the celestial spheres as signs of the elegant wisdom and power of God, citing Koranic verses about the divine creation. For al-Battani, see Sayılı 1960, 15–16; and Ibn Rusta 1955, 1–6. Such speculations on macrocosm and microcosm eventually grew into a special literature emphasizing the overwhelming greatness and wonders of divine creation, a theme already stressed in the Koran. For such cosmological works that developed in the tenth century, see Anton M. Heinen's commentary in his edition of al-Suyūṭī 1982. Post-tenth-century works, which popularized the view that a greater aware-

ness of the wonders of creation could lead to an acknowledgment of God's greatness, recommended contemplation (*tafakkur*) of the phenomena of nature and the signs (*āyāt*) through which God manifested his power and wisdom. For example the earliest known treatise on Sufism, written by al-Hujwiri (d. 1070s), states: "The mark of *muḥādarat* is continual meditation upon God's signs, while the mark of *mukāshafat* is continual amazement at God's infinite greatness"; see al-Hujwīrī 1976, 373. From the twelfth century onward cosmological works on the wonders of creation (*ʿAjā'ib al-makhlūqāt*) were popular.

33. Allen speculated that vegetal and geometric arabesques "probably conveyed some sort of weak association," but he was reluctant to assign meanings unsupported by contemporary textual evidence. He wrote: "Is there iconographic content to the arabesque and geometry? From a modern standpoint it is tempting to wonder if the arabesque, firmly identified with the vine scroll, somehow refers to the vegetal world, and geometric designs allude somehow to the laws of nature that govern the cosmos, or to the rules of construction by which man constructs such things as buildings. But these are anachronistic ideas when applied to the tenth and eleventh centuries, and there is no contemporary evidence to justify projecting them backward in time. It would be useful to study the distribution of arabesque and geometric designs in the art of this period to see if some pattern emerges that might bear on their associations, since there probably are *some* associations, in at least some cases"; see Allen 1988, 54, 56.

34. Ibn Khaldūn 1967, 2: 130–31.

35. In the tenth century Abu al-Hasan al-ʿAmiri similarly referred to mathematics as "free from contradictions and doubts"; see Rosenthal 1975, 65.

36. For the proportioned script, see commentary by Sabra in Ibn al-Haytham 1989, 2: 99; Abbot 1939; Soucek 1979; Schimmel 1984; Oleg Grabar 1992, 47–92; and Tabbaa 1991. The Seljuq historian al-Rawandi has a chapter on the derivation of letters from the circumference of the circle and its diameter subdivided into ten modular dots—he noted that all other geometric figures derive from the circle and its diameter; see al-Rāwandī 1957–1960, 2: 403–11.

37. For the Ibn al-Bawwab Koran, see Ettinghausen 1977, 170–73; and Rice 1955. For later Korans, see Déroche 1983; James 1980; and idem 1988.

38. Tabbaa 1991, 133, 142–43.

39. Ibid., 141. I would like to thank Dr. Tabbaa for sending me the galley proofs of the second part of his article on Arabic writing in the summer of 1993 before it was published. In it he traced the parallel transformation of monumental inscriptions from angular to cursive, "a transformation that postdated the Qur'ānic one by nearly one century but that seems to have been, at least in part, propelled by similar conditions." In this study, Tabbaa first linked the creation of the floriated kufic script under the Fatimids with political and theological issues. Then he traced the gradual spread from approximately 1075 to 1175 of cursive monumental inscriptions in Iran, Syria, upper Mesopotamia, North Africa, and Egypt, connecting this process with the Sunni revival; see Tabbaa 1994. The time lag observed in the emergence of the cursive script in Korans and its use in official monumental inscriptions parallels the case of the *girih*, a mode of design that seems to have made its earliest appearance in illuminated Korans.

40. Tabbaa 1985, 63; Allen 1988, 85–87; Behrens-Abouseif 1993, 501–2.

41. Bausani 1968.

42. A similar conclusion is reached with respect to the spread of the cursive script from Baghdad in Tabbaa 1994.

43. Hartmann 1975.

44. For religion in the Seljuq and Mongol periods, see Bausani 1968. The religious topography of Iran in the Timurid-Turkmen and Safavid periods is discussed in Amoretti 1986.

45. Pope and Ackerman 1938–1939, 3: 2754, 2756, 2762–63.

46. "The Canons of Painting by Sadiqi Bek," translated as an appendix in Dickson and Welch 1981, 1: 259–69; I have slightly modified the translation, adding the bracketed explanations. This passage from p. 262 is cited and analyzed with examples in Lentz and Lowry 1989, 169ff.

47. Mir Sayyid-Ahmad Mashhadi's text (included in the Amir Ghayb Beg Album, H. 2161, Topkapı Sarayı Müzesi, Istanbul, dated 1564–1565) is translated in Thackston 1989, 356. Another variant of this classification appears in a seventeenth-century Safavid text; see Qāżī Aḥmad 1959, 178: "As in writing there are six basic styles, so in the art of painting seven manners are known: *islīmī, khāṭā'ī, farangī, fiṣālī, abr, akrah, salāmī.*" This shows that the names of the seven modes varied considerably.

48. Pope and Ackerman 1938–1939, 3: 2756, 2763.

49. Dost Muhammad's preface is translated in Thackston 1989, 343.

50. Thackston 1989, 353, 355, 339. One wonders whether the Fatimid preference for the floriated kufic script and for vegetal patterns was informed by a similar set of Shiʿi associations.

51. For the *girih* specialists in the Ottoman court, see ʿĀlī 1926, 68. One of them, Taj al-Din, who is referred to as "*girih-bend*," was conscripted from Damascus by Selim I (r. 1512–1520). The other, Mehmed Beg, who was a student of the painter Osman, was described as the most talented among the *girih* masters (*girih-bendlerüñ ekṣerinden yek*); he had arrived at the Ottoman court in the early part of Süleyman I's reign (r. 1520–1566). For the creation of the Ottoman classical style, see Necipoğlu 1990b; and idem 1992a.

52. For Mughal inlay decoration, see Koch 1988; and idem 1991.

53. See Paccard 1980; al-Būzjānī 1990–1991; Buzurgmihri 1982; Firishtah Nazhad 1977; and Shiʿrbaf 1982–1983.

54. For the "protomodern" ethos of the early modern Islamic world, characterized by a preoccupation with challenging the past without completely rejecting its cultural heritage, see Necipoğlu 1993a.

55. For such hadith, see part 3, n. 12, above.

56. Ikhwān al-Ṣafā' 1978, 56, 44, 6. For the audience of the Brethren of Purity, see Ibn al-Haytham 1989, 2: 100; the accessibility of their work in Sunni circles is discussed in Kraemer 1986, 165–78.

57. al-Dawwānī 1839, 146–47. See also al-Ṭūsī 1964.

58. Translated in Thackston 1989, 356.

59. Sāʿī 1989, 44, 136, 158, 171.

60. Caʿfer Efendi 1987, 18–20. I have slightly modified Crane's translation.

61. Cited in Cheetham 1991, 59–60.

62. Translated in Thackston 1989, 349.

63. For these terms, see Firishtah Nazhad 1977.

64. This allusion was first noted by Nykl and Bargebuhr; see Grabar 1978, 142.

65. Parts of the poem are repeated in the Hall of the Abencerrajes across the Court of the Lions; see Grabar 1978, 144–50. For the dome of heaven in various architectural traditions, see Lehmann 1945; Smith 1950; and L'Orange 1982.

66. Grabar 1978, 145.

67. Lokmān b. Seyyid Ḥüseyin el-Āṣūrī el-Ḥüseynī, *Sūrnāme* (Book of festivities), MS H. 1344, fol. 4v, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul.

68. Fakhry 1983, 27; see also chaps. 1, 4, 5, and 8.

69. Ibid., 248. See also al-Ghazālī 1952.

70. For the concept of "naturalization," see Sabra 1987b, 223–43.

71. For the heavenly iconography of the ceiling in Palermo, see Simon-Cahn 1985; the homily is cited on p. 3.

72. Translated in Gelfer-Joergensen 1986, 160–61.

73. Ibn Bībī 1959, 148.

74. Translated in Thackston 1989, 85.

75. See Khwāndamīr 1954, 3: 394, where he referred to "*gunbād-i fīrūze-i muqarnas-i gardūn,*" translated as "the turquoise-stalactited dome of the celestial sphere" in Thackston 1989, 103. Similarly, in his biographical work on poets, Dawlatshah referred to "*haft ṭāq-i muqarnas,*" cited (together with other textual references to muqarnases) in ᶜAbd al-Razzāq al-Samarqandī 1843, 497.
76. Jaᶜfarī 1960, 140–41.
77. al-Kāshī 1960, 19.
78. Translated in Golombek and Wilber 1988, 1: 139.
79. For the increasing use of Persian poetic inscriptions in Timurid architecture, see O'Kane 1989.
80. For Jami's *Al-Durra al-fākhira* (The precious pearl), a treatise that analyzes questions that Islamic theologians, philosophers, and Sufis had long debated, with a decided preference for the Sufi perspective (either because it reconciles the opposing views of the theologians and philosophers, or because it avoids the problems that their doctrines entail), see Jāmī 1979. See also Nawā'ī 1984, 1965–1968.
81. Cited in Subtelny 1983, 124. See also O'Kane 1989.
82. Translated in Golombek and Wilber 1988, 1: 385.
83. For two histories of Yazd, see Jaᶜfarī 1960; and al-Kātib 1966. For the Persian inscription of the Çinili Köşk, which compares its "emerald dome" decorated with stars to the dome of heaven and the kiosk itself to a heavenly mansion touching the constellations, see Necipoğlu 1991, 216. Heavenly metaphors also abound in Khwandamir's *Humāyūnnāma* (Book of Humayun) in which the Mughal ruler Humayun's building activities are discussed; see Khwāndamīr 1940.
84. Golombek and Wilber 1988, 1: 210.
85. Jones 1982, 66.
86. For al-Buzjani's career and works, see Ibn al-Nadīm 1970, 2: 667–68; Woepcke 1855; Yushkevich 1964, 270–77. The cultural milieu of Buyid Baghdad is discussed in Mottahedeh 1980; and Kraemer 1986.
87. See al-Būzjānī, *Kitāb fīmā yaḥtāju ilayhi al-ṣāniᶜ min aᶜmāl al-handasa,* MS Ayasofya 2753, Süleymaniye Kütüphanesi, Istanbul. For a Persian translation of this Arabic manuscript (MS Persan 169, sec. 23, fols. 141v–179v, Bibliothèque Nationale, Paris), see al-Būzjānī 1990–1991. Woepcke based his observations on the Paris manuscript; see Woepcke 1855. Surviving manuscripts of al-Buzjani's practical geometry are listed in Sezgin 1974, 321–25. For meetings in which professional mathematicians and practitioners of the crafts exchanged ideas, see Özdural 1995.
88. I would like to thank Dr. Howyda al-Harithy for this reference in al-Maqrīzī 1987, 2: 362–63.

PART 4. GEOMETRY AND THE CONTRIBUTION OF MATHEMATICAL SCIENCES

Ars sine scientia nihil est (*Art without science is nothing*).

—Jean Mignot, consultant on the fabric of Milan cathedral[1]

CHAPTER 8. THEORY AND PRAXIS: USES OF PRACTICAL GEOMETRY

The context of the Topkapı scroll can be broadened by linking its geometric language with the historical development of the mathematical sciences, the discipline in which premodern Islamic architectural practice was embedded. Unlike the Latin West the Islamic world gained access to the *Elements of Geometry* by the Greek mathematician Euclid (circa 330–260 B.C.) as early as the eighth century when it was translated into Arabic for the Abbasid caliph Harun al-Rashid (r. 786–809), followed by a second translation made for his son al-Ma'mun (r. 813–833). By 987–988, when the bookseller Ibn al-Nadim compiled in Baghdad his *Fihrist* (Index), an annotated catalog of books available in the Arabic language, the major classics on mathematics had been translated and augmented by new Arabic works. The *Fihrist's* list of books written by "geometricians, arithmeticians, musicians, calculators, astrologers, makers of instruments, and persons interested in mechanics and dynamics" testifies to the vast amount of knowledge accumulated in the sciences of the quadrivium (arithmetic, geometry, music, and astronomy). These mathematical works must have had as great an impact on Islamic architectural practice as those that became available in post-twelfth-century Europe would have on Gothic design; the latter included Euclid's *Elements* translated by Adelard of Bath from Arabic into Latin circa 1126, translations of other works by Greek and Muslim authors, and practical geometry manuals.[2]

Arabic science flourished in the early ninth century when Baghdad turned into the cosmopolitan intellectual center of the Abbasid empire with the establishment in 832 of the *Bayt al-ḥikma* (House of wisdom) by al-Ma'mun, the same caliph who proclaimed Muʿtazilism an official doctrine. This scientific institution, whose principal activity was the translation of Greek texts, is believed to have been modeled on the Sasanian academy in Jundishapur, a major school of Hellenistic learning that was still flourishing in the eighth century when it provided the Abbasid court in Baghdad with physicians and astronomers. The Greco-Hellenistic tradition of learning developed in the school of Alexandria was not only transferred to Jundishapur, but also to such centers as Antioch, Edessa, and Harran before its last remnants reached Baghdad in the ninth century. Harran in northern Mesopotamia was the center of the pagan Sabaeans, a sect of star-worshipers who had synthesized the late antique Neoplatonic heritage of the Alexandrian school with Pythagorean-Hermetic elements and Babylonian astrology. As late as the tenth century they were noted for their artistic skills, astrolabe makers, and their temples constructed in the form of pure geometric shapes dedicated to the Primal Cause and the celestial bodies. Harran played an important role in the transmission of Greek science. It not only provided the Abbasid court with such famous translators as the astronomer-mathematician Thabit b. Qurra (826–901), under whose guidance the Sabaeans translated numerous Greek works on mathematics and astronomy into Arabic, but also produced leading scientists specializing in mathematical and astronomical studies. Scholars from different parts of the Muslim world continued to frequent Harran to study astronomy and mathematics well into the eleventh century after which the Sabaeans were

persecuted and their temples destroyed.[3]

According to Hunayn b. Ishaq (d. 877), the Arabic translator of Greek works attached to the *Bayt al-ḥikma,* the traditions of the late school of Alexandria were still very much alive among the scholars and physicians of Baghdad during the ninth century. The translation into Arabic of works in Greek, Syriac, Persian, and Sanskrit had already started during the reign of Harun al-Rashid, but this activity became intensified in his son al-Ma'mun's *Bayt al-ḥikma.* Although this caliphal institution does not seem to have survived the orthodox reaction of al-Mutawakkil, its cultural repercussions proved irreversible. The translations it generated were far from a marginal experiment. They contributed to the assimilation of classical science and philosophy into medieval Islamic culture, even in the traditionist circles of the Sunni revival where ninth- and tenth-century intellectual developments colored by heterodox Muᶜtazili or Shiᶜi orientations were reformulated according to orthodox sensibilities.

After the initial period of translations was over, original contributions were made in such mathematical disciplines as astronomy, optics, algebra, and trigonometry that encouraged the development of geometry in previously unknown directions promising new applications in a number of fields, including architecture and the decorative arts (e.g., arch and dome profiles, geometric patterning, and the muqarnas).[4] The systematic popularization of theoretical mathematics in Baghdad through practical manuals also facilitated its rapid dissemination to other Islamic courts. By the eleventh century the mathematical sciences had become so widespread and achieved so much prestige that even some rulers boasted expertise in them. For example the Ghaznavid ruler Masᶜud I was not only skilled in geometry but could also draw architectural plans with his own hands. The ruler of Saragossa in Spain, Yusuf al-Mu'tamin b. Hud (r. 1081–1085), compiled his own geometry treatise using the extensive collection of mathematical works in his library.[5] It was in this receptive setting that the *girih* initially spread during the eleventh century when its basic repertory became elaborated in different ways in various local courts that had acquired a taste for geometry.

The unprecedented emphasis of the Baghdad school on balancing theoretical knowledge with practical application had an undeniable impact on Islamic visual culture. The close relationship between theory and praxis can be deduced from various encyclopedic classifications of knowledge, in which the applied sciences consistently occupy an important place alongside their theoretical counterparts. One of the earliest examples of such classifications, the *Iḥṣā' al-ᶜulūm* (Survey of the sciences), was written in the first half of the tenth century by al-Farabi, the renowned philosopher whose father may have belonged to the Turkish bodyguard of the Abbasid caliphs. The writings of al-Farabi, who for many years had settled in Baghdad before joining in 942 the entourage of the Hamdanid ruler Sayf al-Dawla in Aleppo, connect him with the late Alexandrian interpretation of Greek philosophy (an amalgam of Neoplatonism and Aristotelianism) dominant in the Abbasid capital at that time. His *Iḥṣā'* subdivided the mathematical sciences into seven specialized fields (arithmetic, geometry, optics, astronomy, music, weights, and mechanics), each of which had both theoretical (*al-naẓarī*) and practical (*al-ᶜamalī*) branches. Among them practical geometry dealt with lines and figures on a piece of wood when used by a carpenter, on a piece of iron when used by a smith, on a wall when used by a mason, and on a plot of land when used by a surveyor. Al-Farabi concluded that practical geometry thus found an application in every craft.[6]

The impact of al-Farabi's writings on such late tenth-century authors as the Brethren of Purity and the Khurasanian philosopher Abu al-Hasan al-ᶜAmiri (d. 992) manifests itself in their similar classifications of mathematical sciences. For example, the collection of encyclopedic epistles, or *Rasā'il,* of the Brethren (an anonymous group inspired by an eclectic mixture of Neoplatonic, Pythagorean, Hermetic, and Sabaean thought) also divides mathematics into theoretical and practical parts. It stresses the role of practical geometry in developing those skills required in all the crafts, while theoretical geometry is identified as the gateway to higher levels of theoretical knowledge, culminating in metaphysics.[7] Al-ᶜAmiri, who enjoyed the patronage of the Buyid vizier Ibn al-ᶜAmid (d. 971) while he lived in Iran (he visited Baghdad at least twice in the 970s) identified five branches of mathematics (arithmetic, geometry, astronomy,

music, and mechanics), describing geometry as a practical field with many applications:

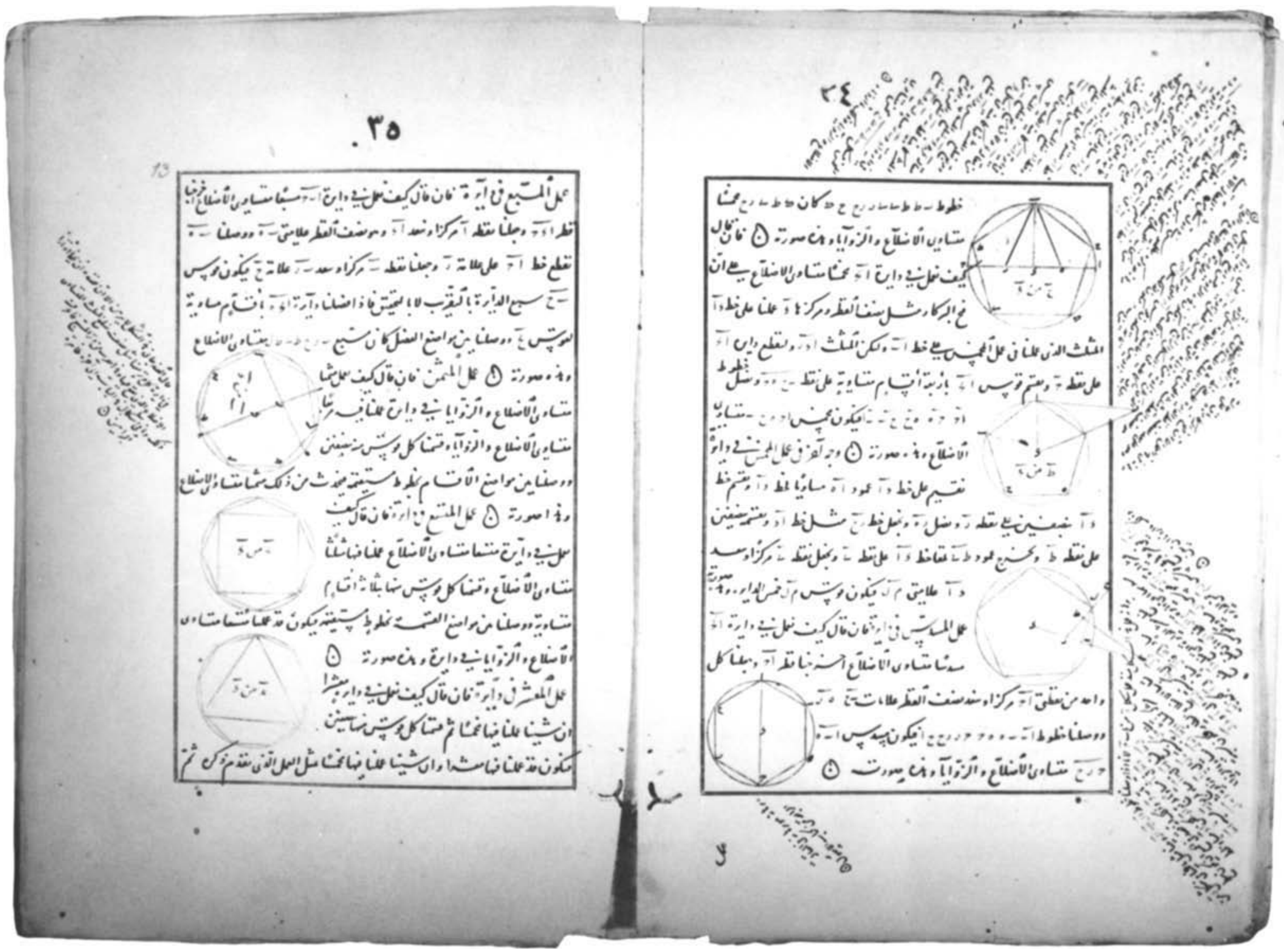
> Geometry follows arithmetic in value and importance. It is easier to understand because it is concerned with sensual prototypes, and it is more far-reaching, for without its aid the arithmetician cannot extract irrational roots, nor the surveyor determine the shapes of sites, nor human reason calculate the extent of the seas and the height of mountains. Besides it is useful to all gifted architects, carpenters, sculptors and goldsmiths and used for the manufacture of astronomical instruments as, for example, spheres [spherical astrolabes?], astrolabes, armillary spheres and sun clocks.[8]

This account of the uses of practical geometry in fields such as land surveying, architecture, the decorative arts, and mechanical engineering once again underlines the intimate connection between theory and praxis. Al-Farabi's earlier statement that practical geometry provides an application in every craft is particularly significant because al-Buzjani's late tenth-century manual on that subject, the *Aʿmāl al-handasa,* which directly addressed the needs of artisans, is believed to have been modeled on an earlier geometry treatise attributed to al-Farabi.[9] In both al-Farabi's and al-Buzjani's treatises the circle, on which the spherical forms and motions of the celestial bodies are based, occupies a prominent position, as it did in the geometrically shaped Sabaean temples.[10] The circle, which came to be regarded as the most beautiful of all geometric figures by the end of the Hellenistic era, is used in al-Buzjani's treatise to generate all of the regular polygons in a plane as well as the sphere, the source of the five regular polyhedrons (Platonic solids) and two of the twelve semiregular polyhedrons (Archimedean solids) with which the work culminates.

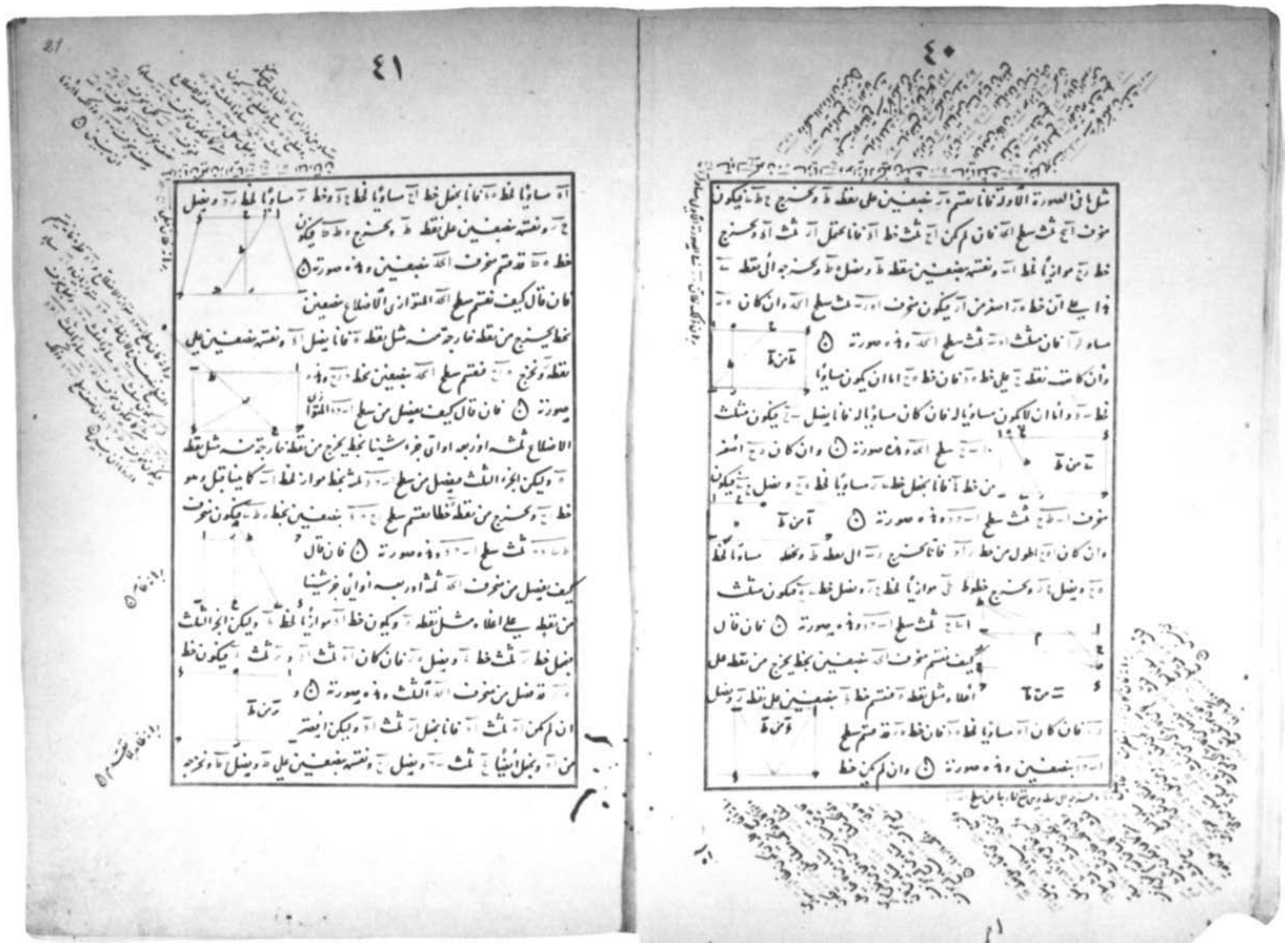
The practical geometries of al-Farabi and al-Buzjani built upon the heritage of the late Alexandrian school. The Neoplatonic philosopher Proclus (410–485), who had studied there, regarded Euclid as a member of the ancient Platonic academy and considered the ultimate purpose of the *Elements* (which ends with the five regular polyhedrons) to be the construction of the five cosmic elements with which Plato's (circa 428–347 or 348 B.C.) *Timaeus* correlates the regular polyhedrons. The Abbasid philosopher al-Kindi (d. circa 866), who integrated Neoplatonism into the official Muʿtazili theology, wrote an epistle, *Risāla fī al-sabab alladhī lahū nasabat al-qudamā' al-ashkāl al-khamsa ilā al-uṣtuqusāt* (About the reason why the ancients related each of the five polyhedrons to the elements), that shows how deeply Neoplatonic cosmology had permeated the Baghdadi milieu.[11] Although the symbolism of the Platonic solids is not articulated in al-Buzjani's practical geometry, this mathematician-astronomer, who wrote the treatise *Kitāb maʿrifa al-dawā'ir min al-falak* (Book on the knowledge of the circle from the heavens), was no doubt aware of the cosmic associations of geometric figures. Given the interdisciplinary link between arithmetic, geometry, astronomy, and music, an interchange between those fields was natural. Especially since most mathematicians in the medieval Islamic world were to some degree involved with astronomy, the predominant use of orbitlike radial grids in generating *girih*s may partly have been inspired by a mentality that assigned the most privileged place among geometric figures to the circle.[12]

Al-Buzjani's *Aʿmāl al-handasa* was brought to light in the 1850s by the historian of science Franz Woepcke, who studied its early eleventh-century Persian translation included in a mathematical anthology preserved at the Bibliothèque Nationale in Paris, MS Persan 169.[13] Its direct relevance for the composition of Islamic geometric patterns was first noted by Prisse d'Avennes (who mentions Woepcke's study), followed by several modern scholars (figs. 99–102). This relevance becomes apparent in an anonymous Persian treatise, appended to the Persian translation of al-Buzjani's text in the Paris manuscript, which thus far is the only known practical manual that provides "how-to" instructions for drawing two-dimensional *girih* patterns. The anonymous treatise, entitled *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), hereafter referred to by its shorter title, *Aʿmāl wa ashkāl* (Constructions and figures), shows that the *girih* mode was conceived as a system of proportionally related geometric patterns

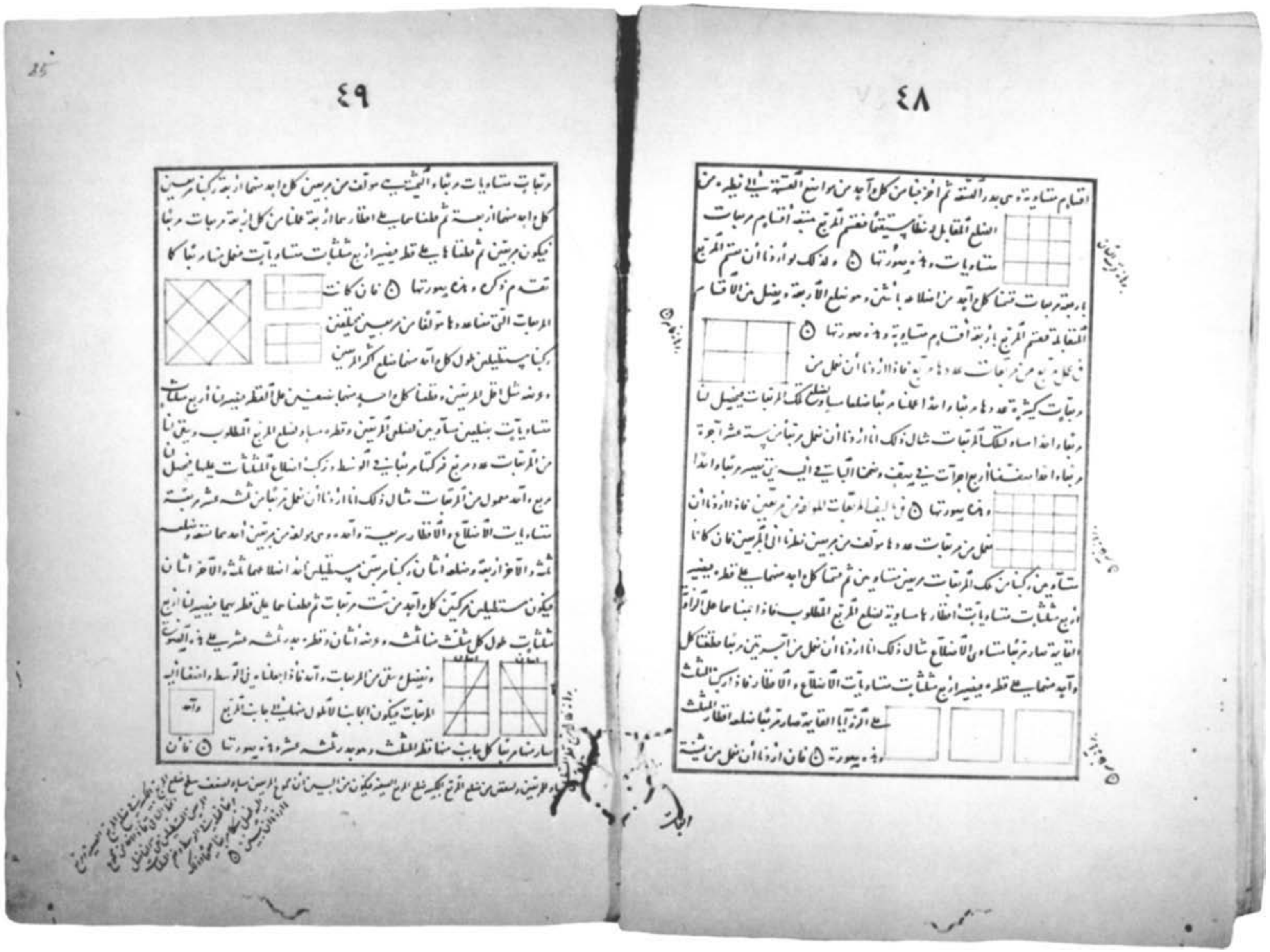
99. Abu al-Wafa' al-Buzjani, folios showing text and geometric figures. From his *Kitāb fīmā yaḥtāju ilayhi al-ṣāniʿ min aʿmāl al-handasa* (About that which the artisan needs to know of geometric constructions), a late tenth-century Arabic manual of practical geometry, copied for Ulugh Beg's royal library in Samarqand, fifteenth century, red and black ink on paper. Istanbul, Süleymaniye Kütüphanesi, MS Ayasofya 2753, fols. 20, 21.



100. Abu al-Wafa' al-Buzjani, folios showing text and geometric figures. From his *Kitāb fīmā yaḥtāju ilayhi al-ṣāniʿ min aʿmāl al-handasa* (About that which the artisan needs to know of geometric constructions), a late tenth-century Arabic manual of practical geometry, copied for Ulugh Beg's royal library in Samarqand, fifteenth century, red and black ink on paper. Istanbul, Süleymaniye Kütüphanesi, MS Ayasofya 2753, fols. 34, 35.



101. Abu al-Wafa' al-Buzjani, folios showing text and geometric figures. From his *Kitāb fīmā yaḥtāju ilayhi al-ṣāniʿ min aʿmāl al-handasa* (About that which the artisan needs to know of geometric constructions), a late tenth-century Arabic manual of practical geometry, copied for Ulugh Beg's royal library in Samarqand, fifteenth century, red and black ink on paper. Istanbul, Süleymaniye Kütüphanesi, MS Ayasofya 2753, fols. 40, 41.



102. Abu al-Wafa' al-Buzjani, folios showing text and geometric figures. From his *Kitāb fīmā yaḥtāju ilayhi al-ṣāni' min a'māl al-handasa* (About that which the artisan needs to know of geometric constructions), a late tenth-century Arabic manual of practical geometry, copied for Ulugh Beg's royal library in Samarqand, fifteenth century, red and black ink on paper. Istanbul, Süleymaniye Kütüphanesi, MS Ayasofya 2753, fols. 48, 49.

harmoniously interlocking with one another. Dates ranging from the early eleventh to the early thirteenth century have been proposed by various scholars for this treatise to which I will return in the next chapter.[14] Its importance lies in documenting an intimate link between the type of practical geometry popularized in late tenth-century Baghdad by such mathematicians as al-Buzjani and the later scroll tradition.

Al-Buzjani's *Aᶜmāl al-handasa* contains an introduction that is a slightly modified version of the one attributed to al-Farabi.[15] This introduction discusses the three basic instruments necessary for geometric constructions, that is, the ruler, set square (angle bracket), and compass with a single opening. In simple language the rest of al-Buzjani's manual teaches the method of drawing regular geometric figures (both plane and solid), subdividing them proportionally into congruent parts, and circumscribing or inscribing them within one another through the use of these basic instruments, with no recourse to arithmetic or to metric considerations. Since al-Buzjani was providing simplified "how-to" procedures derived from advanced mathematical theory for artisans, he did not attempt to support them by scientific demonstrations and proofs.

The manual begins with such basic problems as the construction of a right angle; the bisection of a square or circle; the division of a right angle into equal parts; the trisection of an angle; drawing a line parallel to, perpendicular to, or at a certain angle to a given line; determining the center of a circle or its arc; dividing the circumference of a circle into equal arcs; dropping a tangent to a circle from a given point; drawing a tangent to a circle through a point on it; trisecting the arc of a circle; duplicating a cube and a sphere; and constructing burning mirrors (a subject belonging to mechanics, which is a subfield of practical geometry).[16] From these general problems al-Buzjani moved on to the construction of regular polygons inscribed in circles (see figs. 99, 100), other constructions involving circles and arcs, and the construction of polygonal figures inscribed in various figures. He then turned to the proportional division of triangles, quadrilaterals (see fig. 101), polygons, and circles. His manual also deals with dividing a square into a given number of smaller squares and composing a square from a given number of smaller squares (see fig. 102), finally turning to the division of the sphere's surface into a given number of polygons by inscribing in it the five regular polyhedrons and two of the twelve semiregular polyhedrons.

In short, al-Buzjani's practical geometry outlines basic mechanical methods for constructing, proportionally subdividing, and symmetrically multiplying geometric figures, further simplified by the use of only a single opening of the compass.[17] It reduces complex problems that involve conic sections, such as the trisection of an angle or the doubling of a cube, to simple mechanical procedures providing approximate solutions. Al-Buzjani's constructions of plane and solid geometry (which freely drew on the findings of earlier Greek and Arab mathematicians) had direct relevance for applied fields relying on a geometric system of proportioning, particularly mechanics, land surveying, architectural design, and the decorative arts.[18] Operations such as the division of squares, rectangles, triangles, polygons, and circles into congruent parts could have obvious applications in the laying out of urban schemes, ground plans, elevations, and ornamental compositions. Moreover, the approximate construction of regular polygons by subdividing circles into equal arcs is precisely the method used in generating two- and three-dimensional star-and-polygon patterns in later scrolls (see figs. 99, 100).

The dynamic axes of symmetry onto which radial grids of concentric circles are superimposed in these scrolls were also drawn according to al-Buzjani's method of proportionally dividing rectangles and squares (corresponding to the frames of repeat units) into congruent parts with diagonals and oblique cuts (see figs. 101, 102). This method of proportional division, treated in Euclid's book *On Divisions of Figures,* also seems to reflect the influence of *Cutting Lines in Ratio* and *Cutting Surfaces in Ratio,* by Apollonius of Perga (circa 241–197 B.C.). These two works complemented Apollonius's influential treatise on conic sections that had been translated into Arabic in ninth-century Baghdad under the supervision of the Banu Musa (Sons of Musa) brothers, the three famous Abbasid geometer-engineers who are reported to have sent their agents to Byzantium to collect scientific manuscripts.[19] Star-and-polygon

patterns, based on the harmonic properties of circles approximately divided into equal arcs and composed in quadrangular repeat units proportionally cut into congruent parts by dynamic axes of symmetry (around which elements rotate or through which mirror axes pass), were further explored in *Aʿmāl wa ashkāl,* the anonymous treatise on interlocking similar or congruent figures, as we shall see in the following chapter.

The geometric constructions of al-Buzjani and those included in the anonymous treatise are the only ones known to have directly addressed artisans, suggesting a degree of literacy at least among their masters. Arithmetic and geometry were two independent but interchangeable modes of expression for the same mathematical concepts, one based on the language of numbers, the other on geometric forms. The latter, much more conducive to the visual thinking and graphic imagination of designers who worked with basic tools, seems to have played a central role in medieval Islamic architectural practice and the decorative arts. Besides elevating the status of architecture and the crafts by giving them a respectable scientific foundation, the abstract language of geometry provided an aesthetic basis for design.

Islamic encyclopedias consistently classify architecture and the crafts together with mechanics as subcategories of practical geometry. Al-Farabi's *Iḥṣā',* for instance, lists architecture among the geometric branches of the science of mechanics (*ʿilm al-ḥiyal*), which also included land surveying or mensuration (*ʿilm al-misāḥa*) and the construction of military machines, musical instruments, burning mirrors, sundials, and ingenious mechanical devices. The term *ḥiyal* (pl. of *ḥīla,* "ruse," "deception") highlighted the status of geometric constructions as cunning artifices reflecting the ingenuity of their creators. As such it is part of the same semantic field as the Greek term *metis* (associated with mechanics and *techne*), the "cunning intelligence" possessed by artisans, mechanics, and architects (e.g., Daedalus). Just like its Latin counterpart *scientia de ingeniis,* then, *ʿilm al-ḥiyal* stressed the intellectual character of ingenious devices and artifices encompassed by the mechanical sciences. The connection between architecture and mechanics, rooted in the ancient works of Alexandrian authors such as the first-century scientist Hero, the philosopher Philo (circa 13 B.C.–circa A.D. 50), and the geometer Pappus (fl. circa A.D. 320), had also been stressed in the Roman architect Vitruvius's *Ten Books on Architecture,* circa 25 B.C. Vitruvius's architectural treatise, which includes sections on land surveying, astronomical devices, burning mirrors, sundials, water clocks, water wheels, hoisting machines, catapults, ballistae, and siege machines, encapsulates the same Greek tradition of applied mechanics that provided the basis for medieval Islamic architectural practice.[20]

The eighth book of Pappus of Alexandria's handbook of geometry, which is devoted to the science of mechanics, divides it into theoretical and practical branches, classifying architecture under applied mechanics. This book, an introduction to the science of mechanics, which was translated into Arabic for the Banu Musa brothers, describes the subjects encompassed by that science:

> The mechanicians of Heron's day say that mechanics can be divided into a *theoretical* and a *manual* part; the theoretical part is composed of geometry, arithmetical astronomy and physics, the manual of work in metals, construction, carpentering, and the art of painting, and the practical execution of these matters. The man who has been trained from his youth in the aforesaid sciences as well as practiced in the aforesaid arts, and in addition has a versatile mind, will be, they say the best inventor of mechanical devices and builder.[21]

It is remarkable to find a definition of the ideal architectural education in a geometry manual referring to a curriculum for the science of mechanics attributed to Hero of Alexandria, an expert on stereometry. The person who mastered the curriculum was called *mechanicus* or *mechanikos* (recalling the Arabic term for geometer-engineer, *muhandis*), a title associated with several late Roman and Byzantine architects including Isidorus of Miletus and Anthemius of Tralles, the architects of the Hagia Sophia in Constantinople. Anthemius, a *mechanicus* who applied geometry to solid matter, is also reported to have possessed some knowledge of painting and sculpture, sug-

gesting that he may have played a role in conceiving the decorative program of the church as well.[22]

Pappus of Alexandria's classification of architecture and crafts such as carpentry and metalwork among the subjects of practical mechanics was inherited by Islam, as al-Farabi's and al-ʿAmiri's tenth-century classifications show.[23] Later Islamic sources continue to mention the role of practical geometry in the training of architects and artisans. The biographical work of the Persian author Abu al-Hasan al-Bayhaqi (1100–1169/1170), for example, cites a saying by the astronomer-mathematician al-Isfizari (d. 1123), who regarded the science of geometry as the basis and foundation of architecture that the architect and the bricklayer had to follow. Another entry about the geometer al-Hakim Abu Muhammad al-ʿAdli al-Qajini establishes a hierarchy based on the differing levels of geometric knowledge required from the designing architect and the mason executing his designs; the architect with his practical knowledge of geometry follows after the theoretical geometrician, and the bricklaying mason comes last. The same hierarchy is mentioned in the thirteenth-century ethical digest of Nasir al-Din al-Tusi who himself was a mathematician. Here again the practical geometry of the architect is contrasted with the superior theoretical knowledge of the geometer, while the craftsman is ranked lowest.[24]

Late medieval and early modern Islamic classifications of the sciences elaborate earlier ones; they cite additional fields of practical geometry that augment the seven-fold list provided by al-Farabi. For example, the *Irshād al-qāṣid ilā asnā' al-maqāṣid fī anwāʿ al-ʿulūm* (Guidance for him who tends to the highest purpose in the various sciences) of Ibn al-Akfani, the Iraqi physician and encyclopedist who died in Cairo in 1348, mentions ten applied branches of geometry. These consisted of optics, burning mirrors, centers of gravity, mensuration, mechanics, clocks, military machines, the construction of buildings, the location of hidden waters, and pneumatic devices, known as the science of ingenious devices. The Ottoman encyclopedist Taşköprizade (1495–1560) counted fifteen applied branches of practical geometry, adding navigation, swimming, pulleys used in construction, catapults, and equalizing time to the fields already cited by Ibn al-Akfani.[25] Taşköprizade, Ibn Khaldun, Ibn al-Akfani, and the Mamluk scholar al-Qalqashandi (1355–1418) all stressed the connection between architecture and practical geometry but did not once mention its debt to arithmetic.[26] That architectural design methods were predominantly geometric is also documented in scrolls whose *girih*s were created by manipulating basic geometric figures and not by arithmetic calculations involving numbers.

The branch of practical geometry that dealt with the foundation, construction, and aesthetics (*ḥusn*) of monuments was known as *ʿilm al-ʿuqūd al-abniya* (lit., "the science of 'knots' of buildings," from *ʿaqd*, pl. *ʿuqūd*, "knots," "vault," or "arch," that is, the science of architectural constructions). This science was concerned with the building of cities, fortifications, beautiful monuments, elevated bridges, subterranean irrigation canals (*qanāt*), and dams. Taşköprizade pointed out that its most outstanding works were two early eleventh-century books, one by the Iraqi mathematician Ibn al-Haytham (Alhazen, 965–1039), who after unsuccessfully attempting to construct a dam on the Nile settled in Fatimid Cairo where he wrote his famous optical treatise, and the other by the Persian mathematician-engineer al-Karaji (d. circa 1019–1020), who held administrative positions in Baghdad and Iran where he wrote several treatises including one on hydraulic water supplies and the construction of *qanāt*s.[27] Several chapters dealing with the science of construction were also incorporated into a now-lost Ilkhanid encyclopedic work, attributed to Rashid al-Din. In this twenty-four-chapter work, the fourth and fifth chapters discussed canals, ditches, and dams; chapters 20 and 21 covered the construction of cities, buildings, fortresses, ships, bridges, and mechanical devices used as building aids.[28]

It is unclear to what extent these works were inspired by classical prototypes such as the architectural treatise by Vitruvius, which is not mentioned in Ibn al-Nadim's tenth-century list of books in Arabic. Although many medieval Vitruvius manuscripts have been documented in Europe, they are not yet known to have circulated in the Muslim world. The only exception seems to be an early fifteenth-century Latin Vitruvius codex from the library of the Hungarian king Matthias Corvinus (1440–1490) in Budapest that was incor-

porated into the Ottoman collection of imperial manuscripts at the Topkapı Palace after sultan Süleyman I's conquest of that city.[29] It is unfortunate that Ibn al-Haytham's *Kitāb al-abniya wa al-ʿuqūd* (Book of buildings and constructions) and al-Karaji's *Kitāb ʿuqūd al-abniya* (Book of architectural constructions) mentioned by Taşköprizade have not survived. The latter, which dealt with the construction of buildings, bridges, and engineering, was described by Ibn al-Akfani as a work exclusively based on practical geometry.[30] Ibn al-Haytham's lost work, on the other hand, was referred to by the physician and biographer Ibn Abi Usaybiʿa (1203–1270) as *Maqāla fī ijārāt al-ḥufūr wa al-abniya bi-jamīʿ al-ashkāl al-handasīya* (Treatise on the construction of ditches and buildings with all the figures of geometry joined together), a work concluding with the three conic sections, namely, the parabola, hyperbola, and ellipse.[31] These lost treatises relying on practical geometry, therefore, appear to have been illustrated with geometric constructions that included conic sections, constructions probably adapted to simplified mechanical procedures.

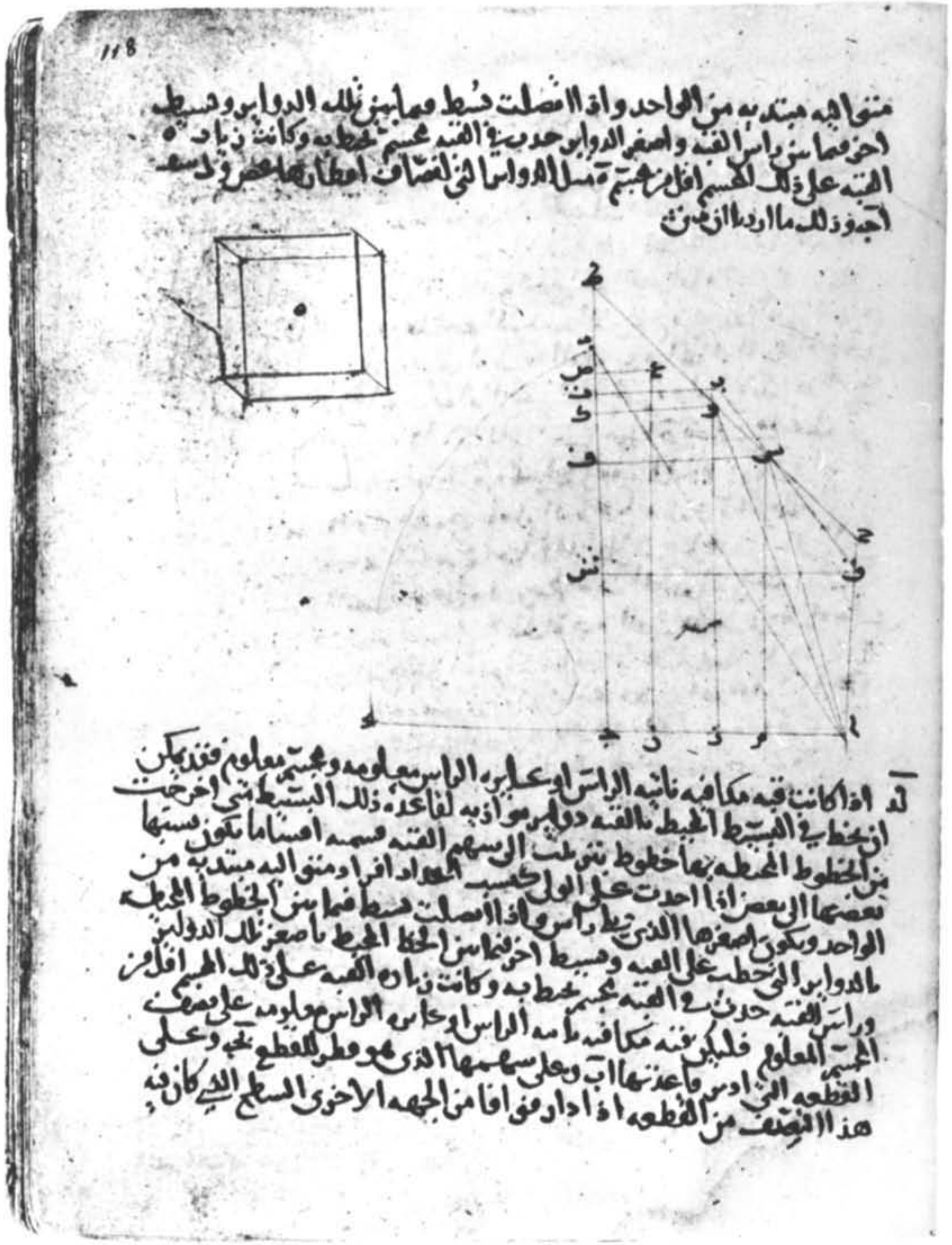
Ibn Khaldun testified to the use of conic sections in architecture and those crafts dealing with bodies:

> Conic sections are a branch of geometry. This discipline is concerned with the study of the figures and sections occurring in connection with cones. It proves the properties of cones by means of geometrical proofs based upon elementary geometry. Its usefulness is apparent in practical crafts that have to do with bodies, such as carpentry and architecture. It is also useful for making remarkable statues [monuments] and large objects [*hayākil,* "effigies," or "edifices"] and for moving loads and transporting large objects [*hayākil*] with the help of mechanical contrivances, engineering [techniques], pulleys and similar things.[32]

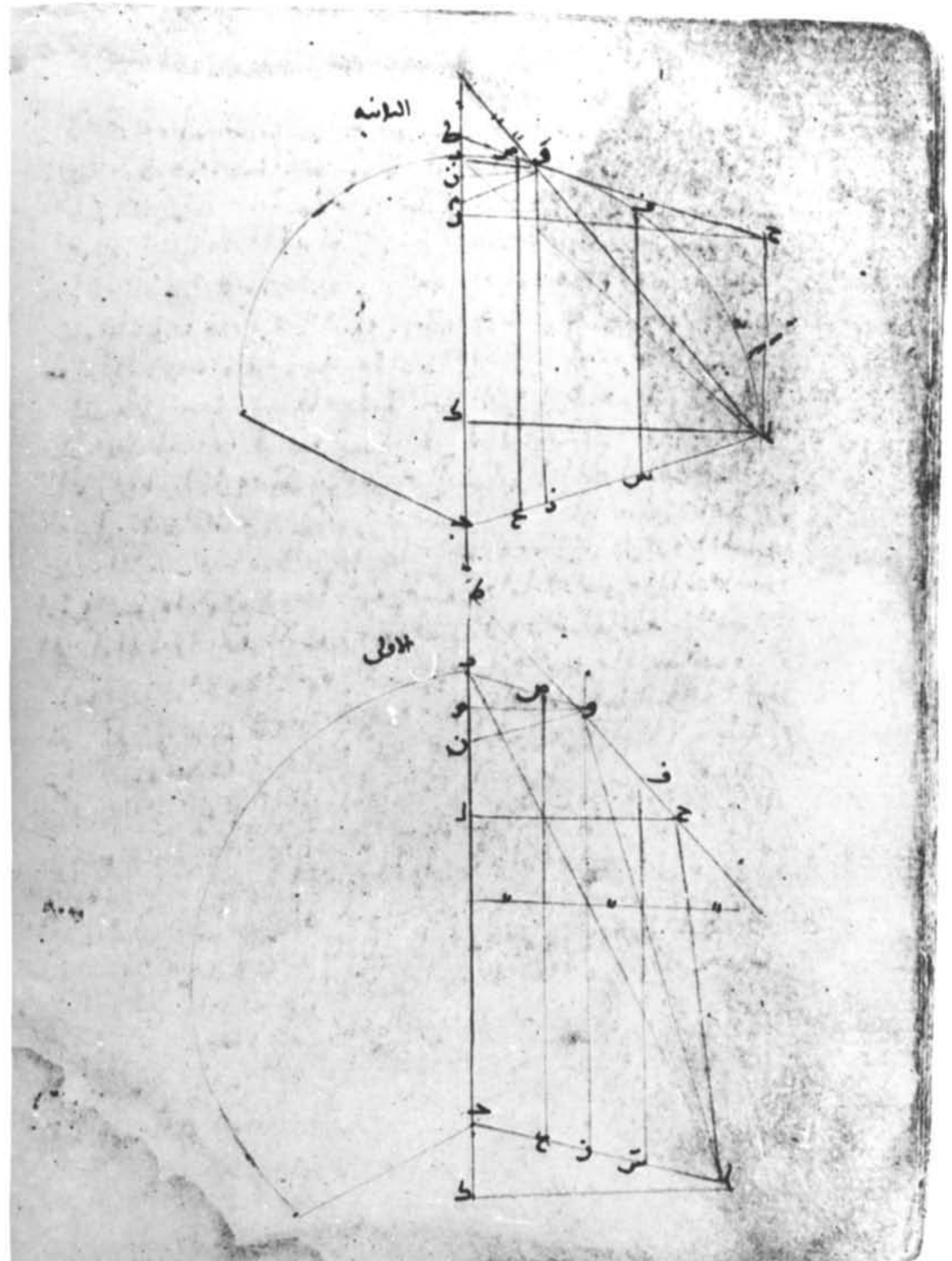
This statement is confirmed in a ninth-century treatise on the mensuration (*misāḥa*) of paraboloids by Thabit b. Qurra, which includes a discussion of the "parabolic dome" (*al-qubba al-mukāfiya*) created by rotating different sections of a parabola, accompanied by drawings of dome profiles (figs. 103–106). Treatises on the mensuration of parabolas and paraboloids were written by such mathematicians as Ibrahim b. Sinan (909–946), al-Sijzi (969–999), Abu Sahl al-Quhi (fl. 980–1000), and Ibn al-Haytham, some of them including sections on arches, vaults, and domes. Al-Sijzi, for example, wrote a work exclusively dealing with the mensuration of domes, entitled *Risāla fī khawāṣṣ al-qubba al-zāʾida wa al-mukāfiya* (Epistle about the characteristics of hyperbolic and parabolic domes).[33]

The many Arabic treatises on conic sections, written after Apollonius of Perga's *Conica* was translated, often deal with problems of practical application.[34] Their contribution to architectural practice (particularly designing pointed arches, vaults, and domes) and to the decorative arts awaits assessment by historians of science so that the ways in which theory and praxis interacted can be understood more clearly. A number of tenth- and eleventh-century mathematicians also are known to have written treatises on drafting instruments that facilitated the sketching of conic sections for scientists (*al-ʿālim*) and artisans (*al-ṣāniʿ*) alike.[35] The existence of such treatises supports Ibn Khaldun's statement that the conic sections, which he identified as a branch of practical geometry, were relevant for architectural and artisanal practice, a statement confirmed by Ibn al-Haytham's lost architectural treatise, which ended with the three conic sections.

One of these drafting instruments is described in the mechanical engineer Ismaʿil b. al-Razzaz al-Jazari's *Kitāb fī maʿrifat al-ḥiyal al-handasīya* (Book on the knowledge of ingenious mechanical devices), written in the first years of the thirteenth century for the Artuqid prince of Diyarbakır (fig. 107). This was a special drafting instrument with the aid of which "the centre-point of three points on the surface of a sphere or on a horizontal surface [provided that they are not in a straight line] can be determined" and with which "other angles in [general use], acute or obtuse, may also be determined." It consisted of a horizontal brass ruler with a semicircular projection at its center (a sextant whose arc was pierced with holes corresponding to different angles) and a perpendicular alidade (Arabic, *al-ʿidāda,* the revolving radius of a graduated circle, the revolving upper arm or index

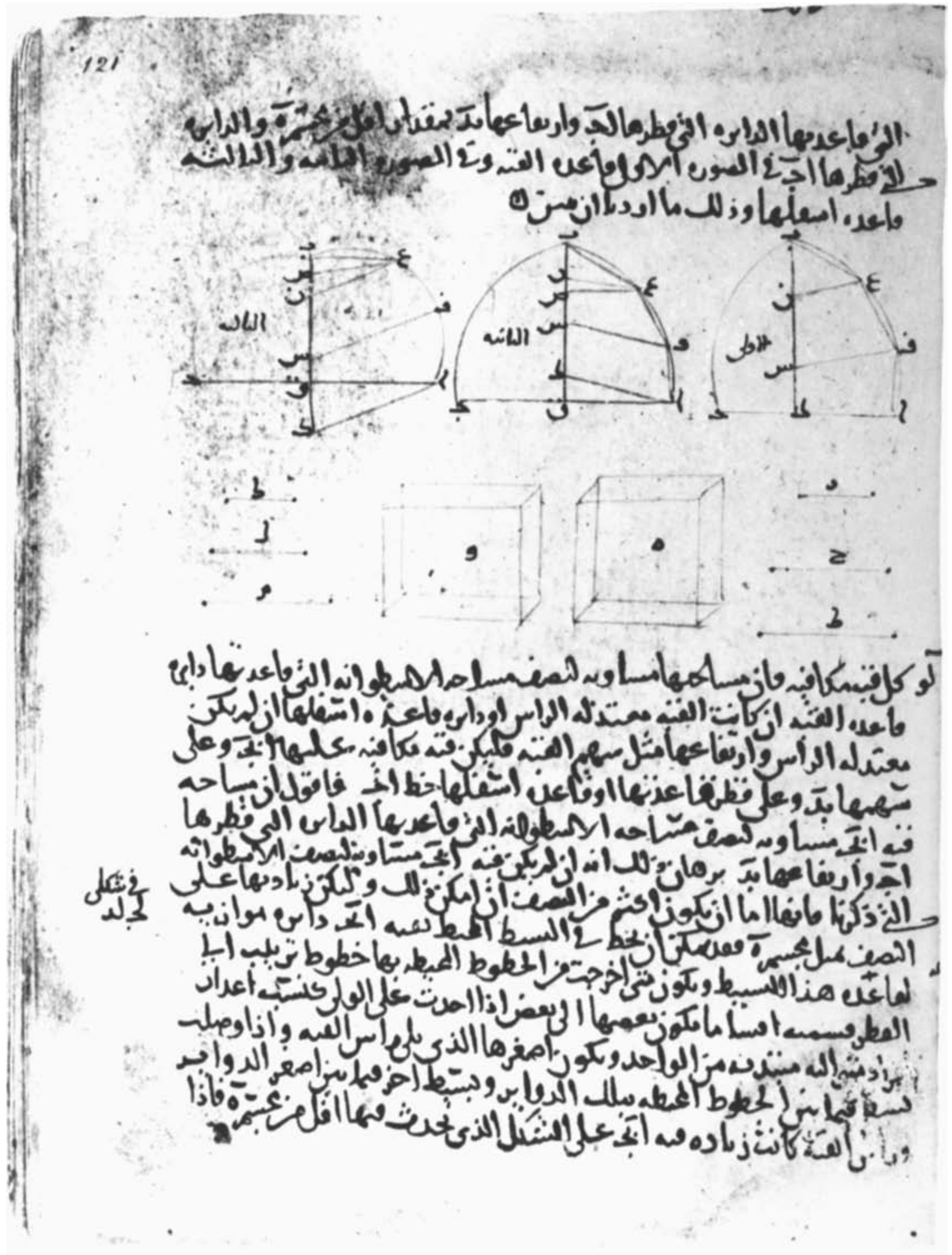


103. Thabit b. Qurra, drawing of a dome profile. From his *Kitāb fī misāḥat al-mujassamāt al-mukāfīya* (Book on the mensuration of parabolic bodies), copied by al-Sijzi in 969, ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Arabe 2457, fol. 118r.

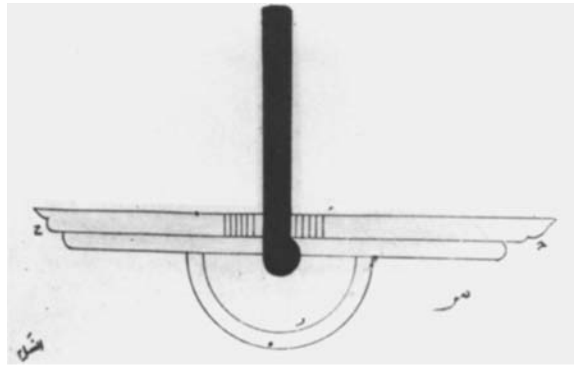


104. Thabit b. Qurra, drawings of dome profiles. From his *Kitāb fī misāḥat al-mujassamāt al-mukāfīya* (Book on the mensuration of parabolic bodies), copied by al-Sijzi in 969, ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Arabe 2457, fol. 119v.

105. Thabit b. Qurra, drawings of dome profiles. From his *Kitāb fī misāḥat al-mujassamāt al-mukāfīya* (Book on the mensuration of parabolic bodies), copied by al-Sijzi in 969, ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Arabe 2457, fols. 121v, 122r.



106. Thabit b. Qurra, drawings of dome profiles. From his *Kitāb fī misāḥat al-mujassamāt al-mukāfīya* (Book on the mensuration of parabolic bodies), copied by al-Sijzi in 969, ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Arabe 2457, fol. 121r.

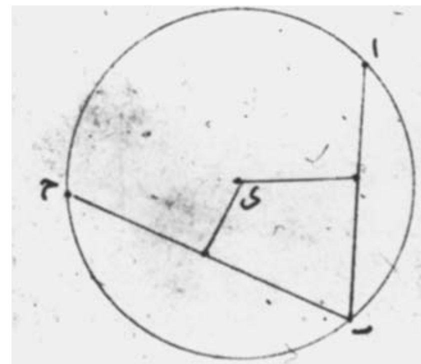


107a. Ismaʿil b. al-Razzaz al-Jazari, drawing of an instrument for setting out different angles. From his *Kitāb fī maʿrifat al-ḥiyal al-handasīya* (Book on the knowledge of ingenious mechanical devices), early thirteenth century, watercolor and ink on paper. From al-Jazarī 1974, 197, fig. 151. Courtesy: The Bodleian Library, University of Oxford, MS Greaves 27, fol. 108v.

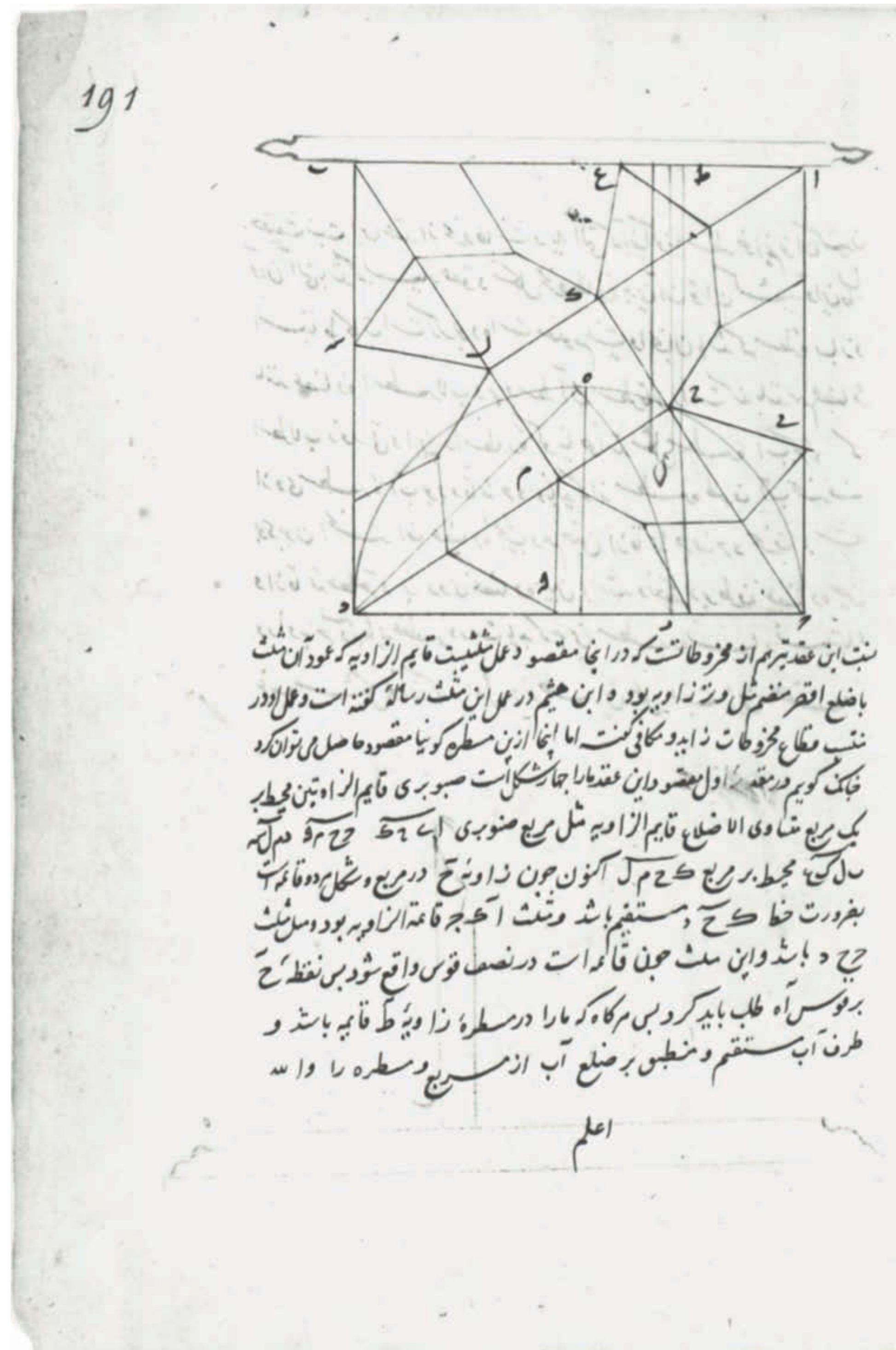
of an astrolabe or any graduated instrument showing the degrees of an arc). It set out right angles when the alidade was at right angles to the horizontal ruler; shifting the alidade's position by aligning it with the angles marked on the arc of the sextant allowed the setting out of various acute and obtuse angles (each corresponding in proportion to two segments of the sextant's semicircular arc).[36]

The same instrument, identified as an angle-bracket ruler (*gūnyā-i misṭara* or *misṭara-i gūnyā*) is described by the anonymous author of *Aʿmāl wa ashkāl* (fig. 108). Here it is mentioned in connection to the construction of a right triangle whose hypotenuse equals the sum of its perpendicular and shortest side, and it is specified that Ibn al-Haytham had written a treatise about the construction of such a triangle based on the intersecting conic sections of a hyperbola and parabola. This construction required the use of the angle-bracket ruler, that is, a ruler with a central perpendicular alidade that could be tilted according to different angles indicated on a protruding graduated arc resembling a protractor. That this instrument was inspired by astrolabes and quadrants giving angle readings in ratios of arcs is suggested by its incorporation of an alidade and a sextant. It facilitated drawing geometric compositions based on conic sections corresponding to rare proportions and angles. With its help some of the more unusual angles used in *girih* patterns, generally drawn with set squares corresponding to more common right angles (e.g., 30-60-90 or 35-45-90 degrees), could be determined.[37] This instrument, then, enabled artisans to cope with conic sections whose complicated construction was not only impractical, but probably beyond their practical knowledge of geometry.

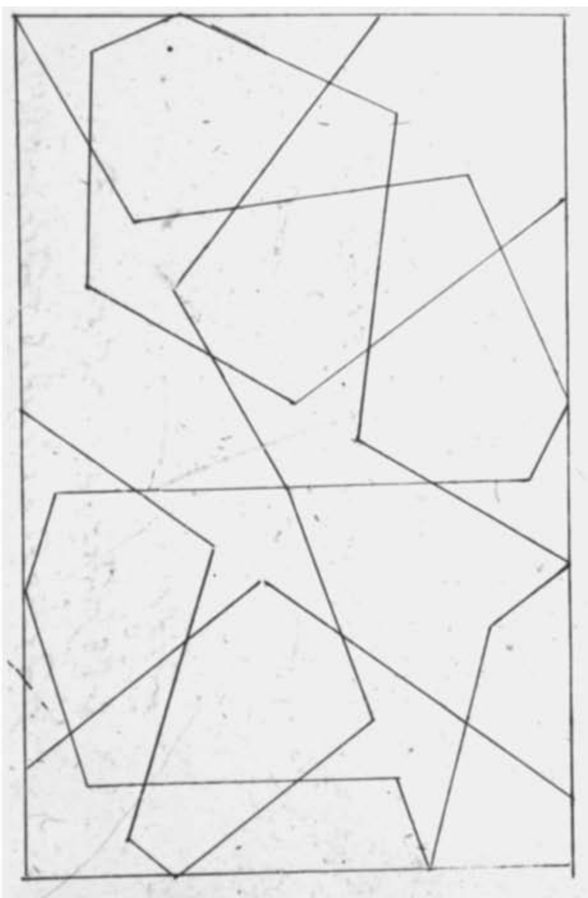
The repeat units of geometric *girih* patterns contained in the anonymous *Aʿmāl wa ashkāl* treatise were based on specific proportional relationships as its title implies (figs. 109–114). The "how-to" instructions in Persian that accompany these *girihs* usually start with the standard phrase: "The way of drawing [*ṭarīq-i kashīdan*] and the ratio or proportion [*nisbat*] of this construction [*ʿaqd*] is as follows" (see the texts in figs. 112, 114).[38] The identification of geometric constructions as *ʿaqd*, the Arabic equivalent of the term *girih*, suggests a direct link between the lost early eleventh-century *ʿuqūd* (pl. of *ʿaqd*) treatises by Ibn al-Haytham and al-Karaji illustrated with geometric schemata and the later Topkapı scroll. It is tempting to speculate that the examples of *ʿaqd* included in the anonymous treatise were not so different from the ones used in architectural treatises. This hypothesis is strengthened by the fact that the science of *ʿuqūd al-abniya* was a subcategory of practical geometry and that Ibn al-Haytham's vanished treatise on this subject included all the figures of geometry joined together. If that was the case, it is no wonder that later scrolls compiled by master builders consist of purely geometric patterns generated by "knots" forming variegated grid networks.



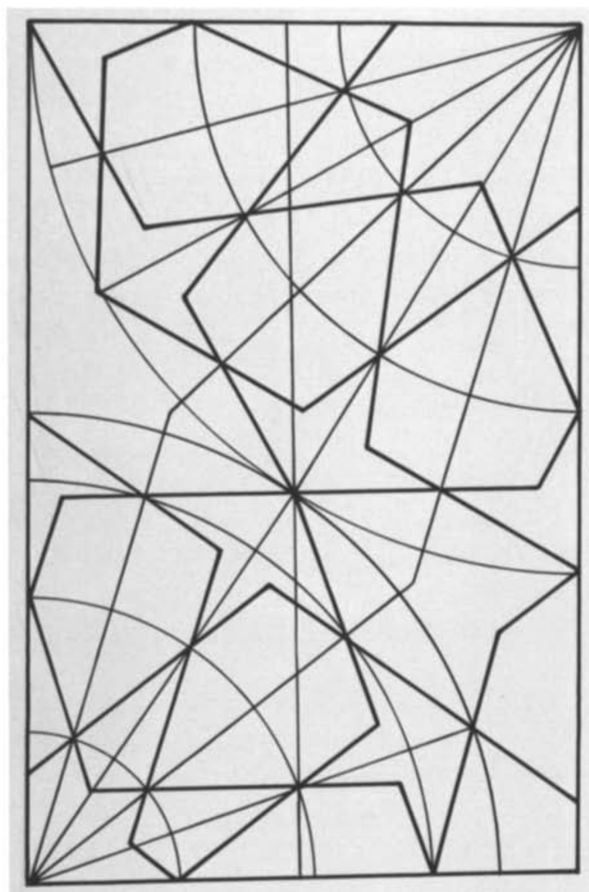
107b. Ismaʿil b. al-Razzaz al-Jazari, diagram showing how to determine the center of three points marked on a circle with the instrument depicted in figure 107a. From his *Kitāb fī maʿrifat al-ḥiyal al-handasīya* (Book on the knowledge of ingenious mechanical devices), early thirteenth century, watercolor and ink on paper. From al-Jazarī 1974, 197, fig. 152. Courtesy: The Bodleian Library, University of Oxford, MS Greaves 27, fol. 109r.



108. Angle-bracket ruler. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, red and black ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 191r.

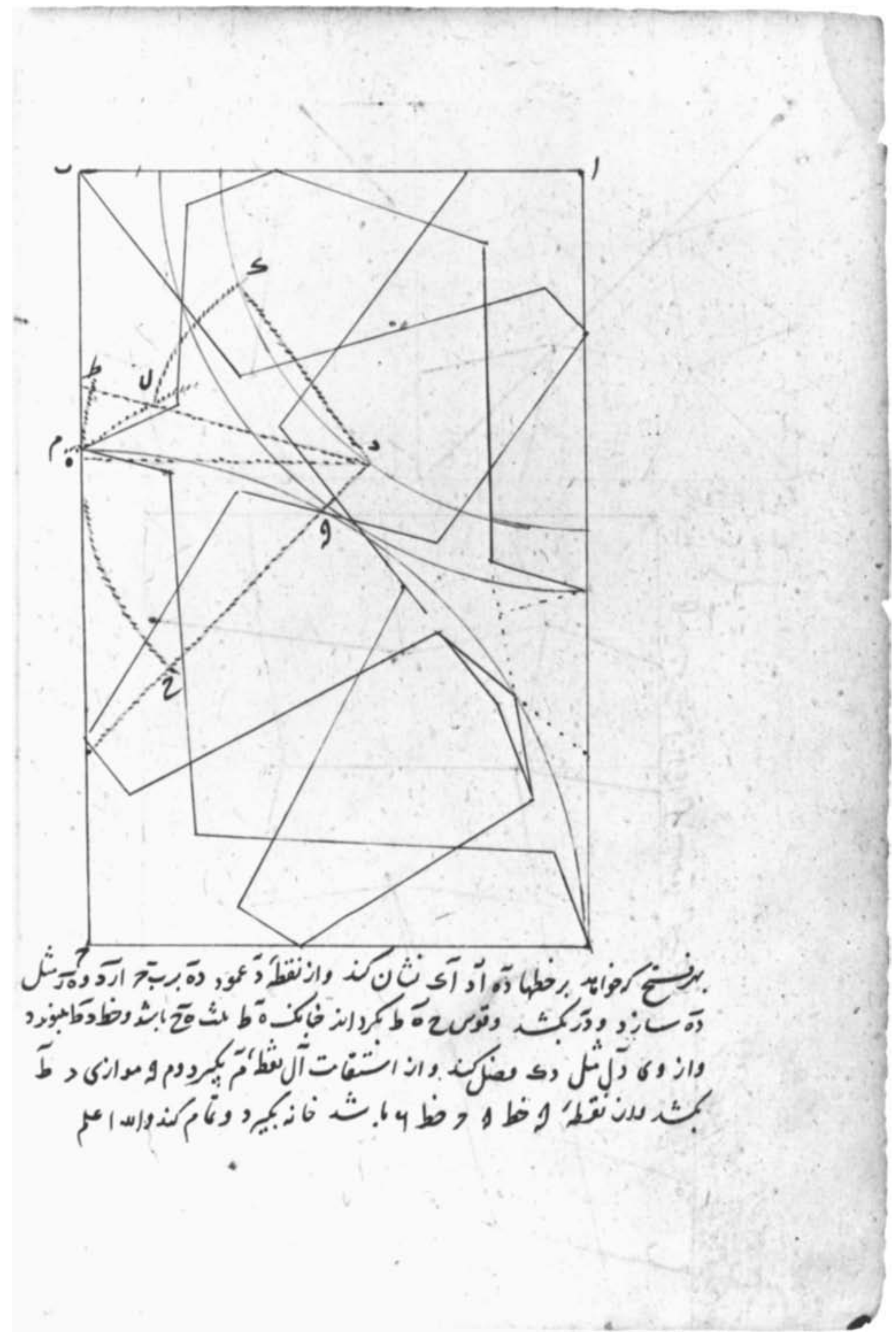


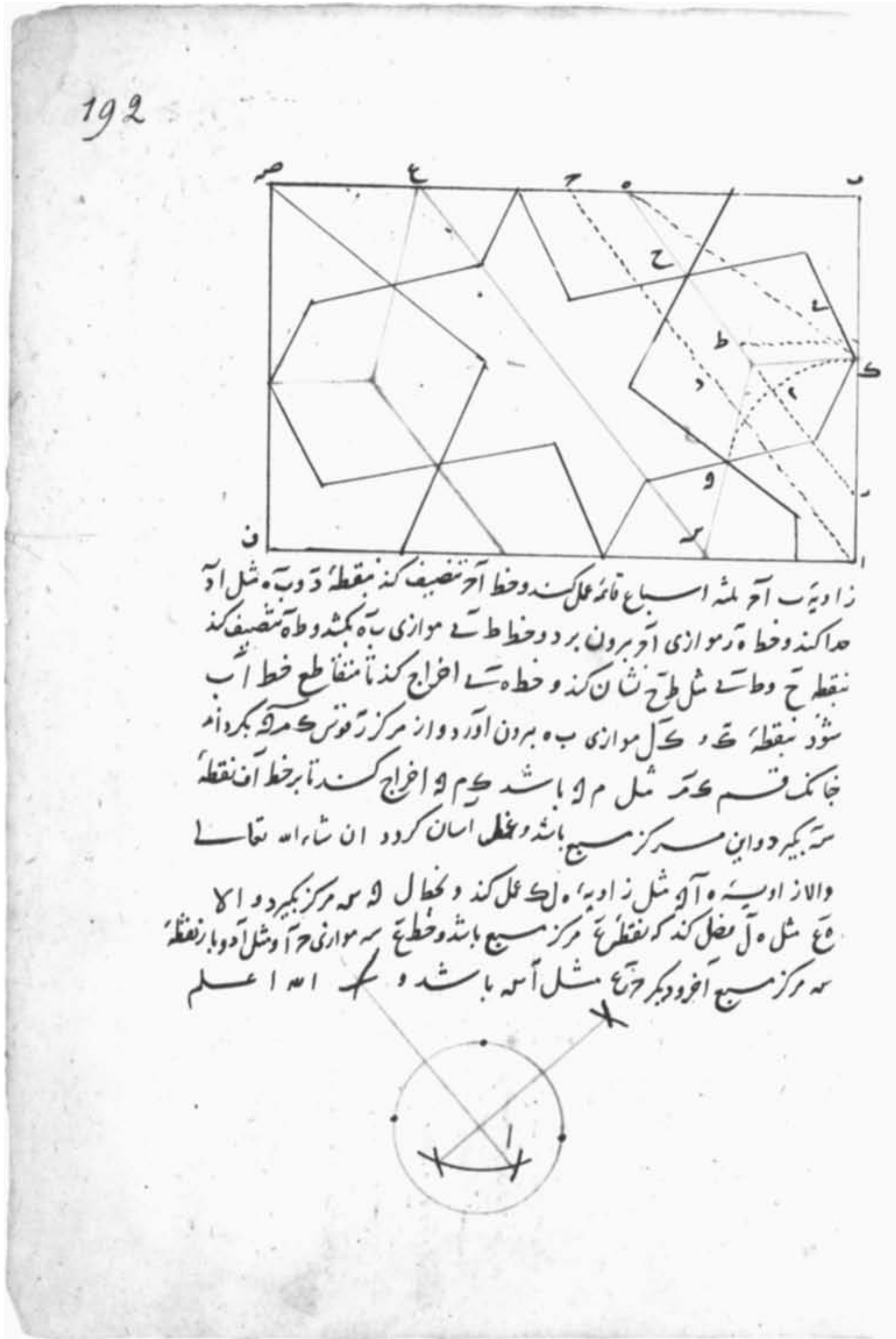
109a. Repeat unit for a star-and-polygon pattern. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 196r.



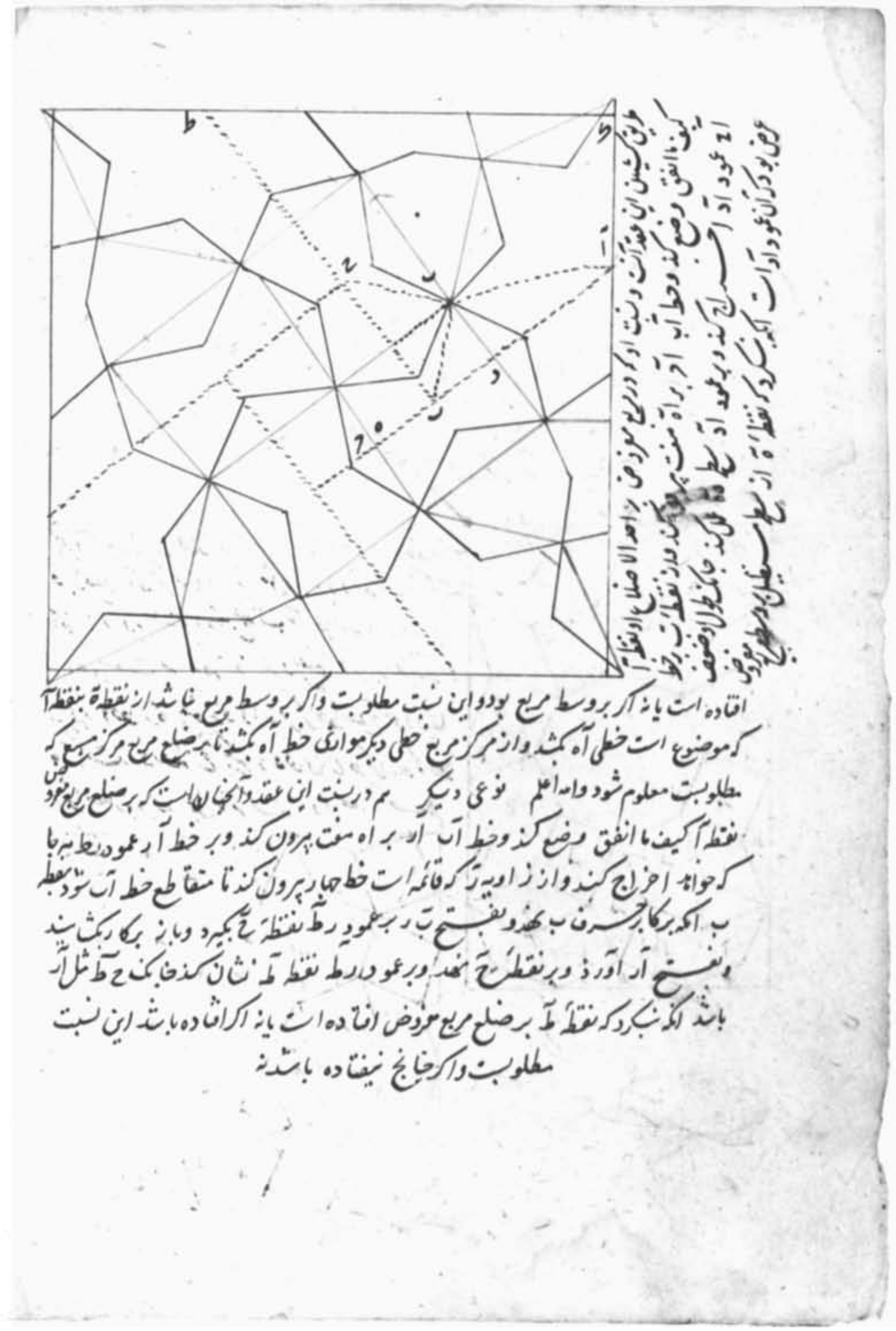
109b. Diagram of uninked grid lines used in generating figure 109a. Drawing by Elizabeth Dean Hermann.

110. Repeat unit for a star-and-polygon pattern. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, red and black ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 195v.



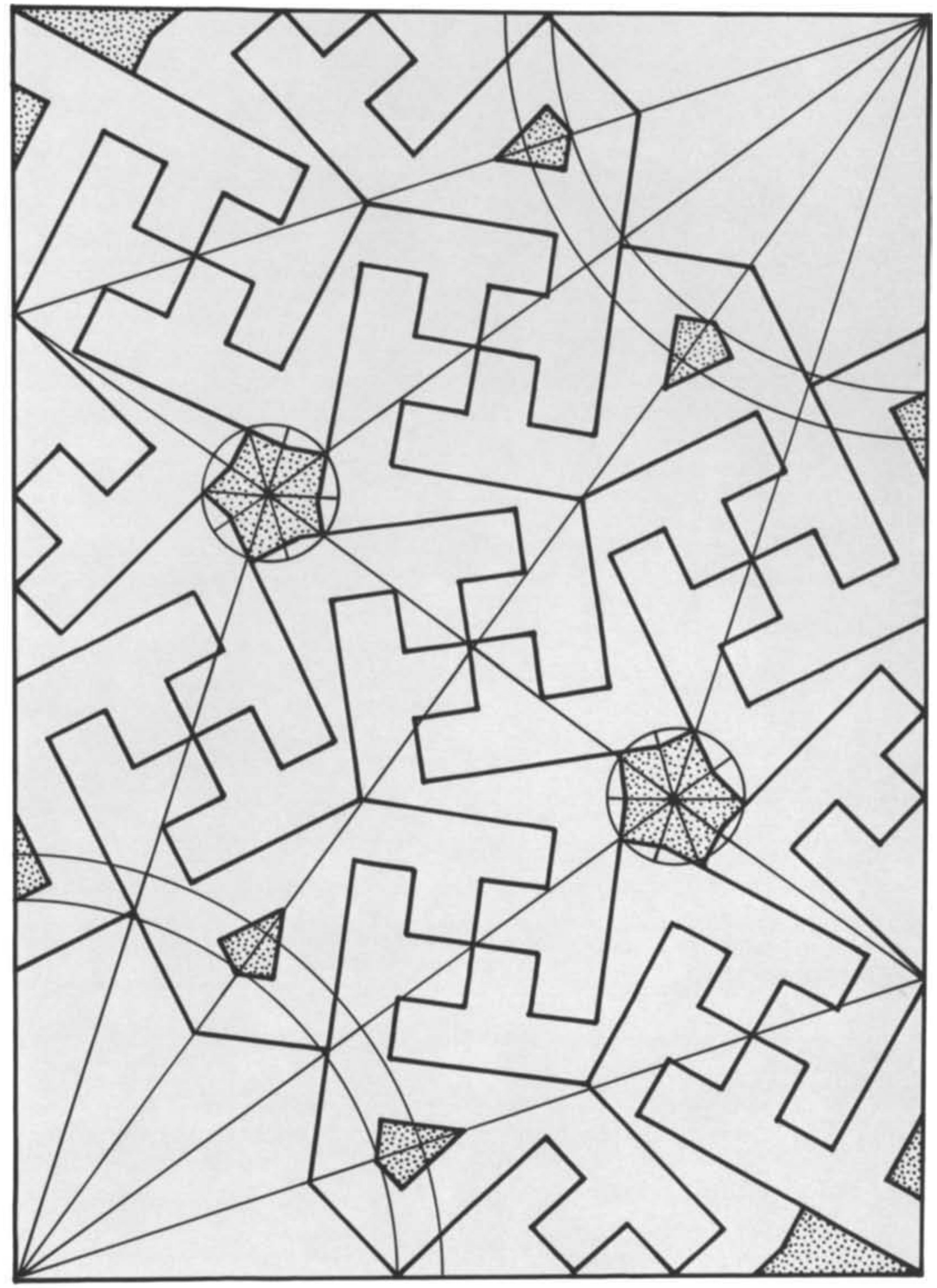


111. Repeat unit for a star-and-polygon pattern. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, red and black ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 192r.



112. Repeat unit for a star-and-polygon pattern. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, red and black ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 194v.

113a. Repeat unit for a star-and-polygon pattern with swastikas. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, red ink and brownish green wash on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 199r.



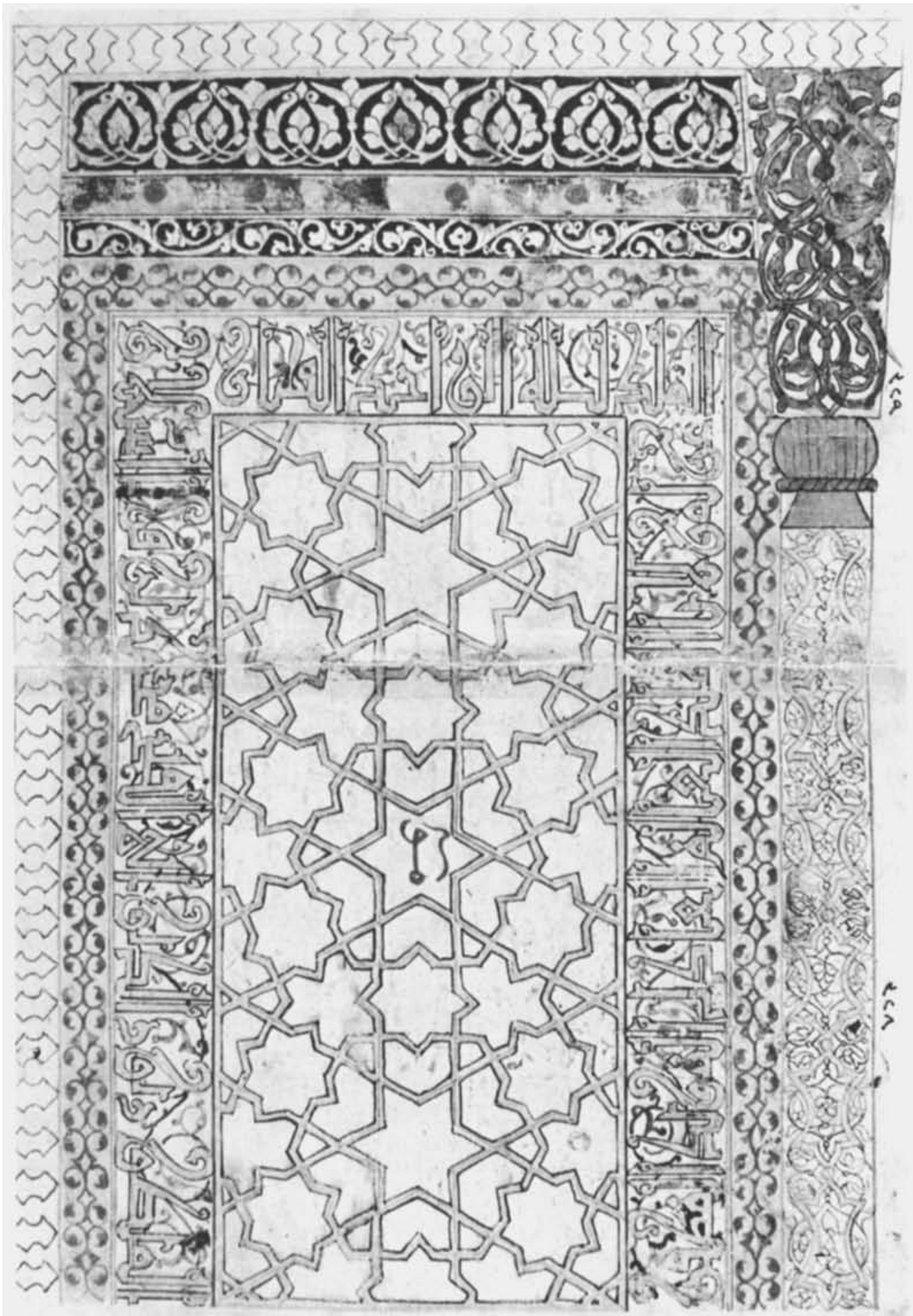
113b. Diagram of uninked grid lines used in generating figure 113a. Drawing by Elizabeth Dean Hermann.

114. Repeat units of patterns, two of which are composed with squares, rhombuses, and octagons. From the anonymous treatise *Fī tadākhul al-ashkāl al-mutashābiha aw al-mutawāfiqa* (On interlocking similar or congruent figures), eleventh to thirteenth century, red and black ink on paper. Photo: Copyright cliché Bibliothèque Nationale de France, Paris, MS Persan 169, fol. 194r.

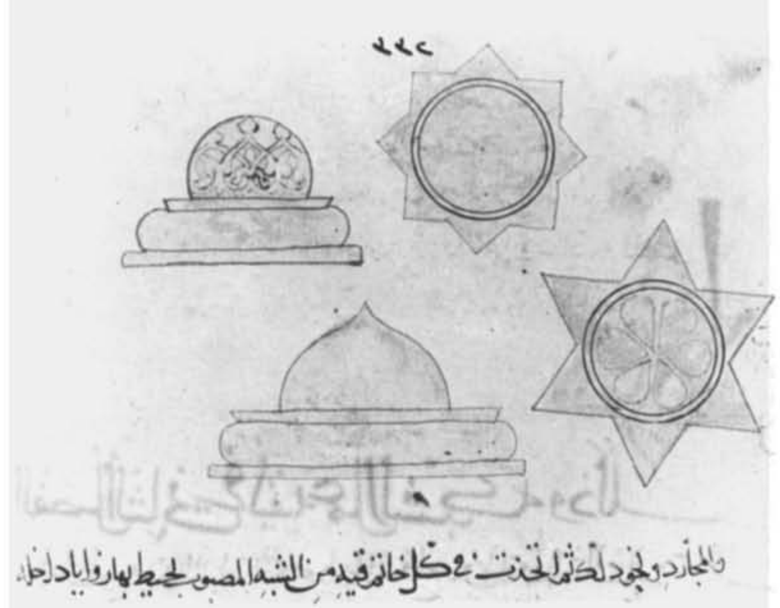
The embeddedness of architectural practice and the allied decorative arts in practical geometry can also be surmised from al-Jazari's early thirteenth-century treatise where the casting of a metalwork door with interlocking geometric pieces is described (figs. 115–117). The important place given to this door (made for the Artuqid royal palace of Diyarbakır) in al-Jazari's treatise on ingenious mechanical devices, one of the earliest manuals of practical mechanics to have survived, shows that Pappus of Alexandria's definition of this field was fully assimilated by medieval Islamic culture. Al-Jazari was a master craftsman fully conversant with the branches of his trade, which included architecture, metalwork, and carpentry. His cast-brass door featured a grid network (*shabaka,* lit., "net") of hexagonal and octagonal stars (*khātim,* lit., "signet ring") joined by rhomboidal filler units. It was decorated with hollow domes, "leaves of various kinds with intertwined stems," and "writing in the Kufic script with intertwined letters" featuring "intertwined leaves." For each geometric unit of the latticework al-Jazari prepared a wooden template (*mithāl*) and, "as the founders do in foundry," cast the pieces in closed mold boxes with green sand. The door's interlocking star-and-polygon patterns, resembling those on "carpenter's work for filling in joinery" (*kārzawān,* lit., "tongue-and-groove joined work"), required a knowledge of practical geometry.[39]

Al-Jazari warned the reader that his written description is less informative than the drawings accompanying it: "This is [best] understood

115. Ismaʿil b. al-Razzaz al-Jazari, schematic design for a cast metalwork door with star-and-polygon patterns. From his *Kitāb fī maʿrifat al-ḥiyal al-handasīya* (Book on the knowledge of ingenious mechanical devices), Diyarbakır, 1206, watercolor and ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS A. 3472, fols. 165v–166r.



116. Ismaʿil b. al-Razzaz al-Jazari, diagrams showing the details for the individual units of a cast metalwork door with star and polygon patterns. From his *Kitāb fī maʿrifat al-ḥiyal al-handasīya* (Book on the knowledge of ingenious mechanical devices), Diyarbakır, 1206, watercolor and ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS A. 3472, fol. 167r.



117. Ismaʿil b. al-Razzaz al-Jazari, diagrams showing the details for the individual units of a cast metalwork door with star-and-polygon patterns. From his *Kitāb fī maʿrifat al-ḥiyal al-handasīya* (Book on the knowledge of ingenious mechanical devices), Diyarbakır, 1206, watercolor and ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS A. 3472, fol. 167v.

by studying the drawing, not from what I have described, for I have abbreviated the description."[40] The importance of technical drawings in communicating practical craft knowledge is revealed in a fascinating passage where al-Jazari described the schematic drafting method he used to make his designs more legible:

> In drawing it [the picture of the door] I have not aimed for completeness. My purpose was to present a [general] arrangement so that it can be understood in the whole and in detail. One realises that there is obscurity in the representations of solid bodies, but in the imagination one can fit one thing to another, view it from an angle, dissect it, and thus assemble it step by step. All the drawings which I have made are simple, so that they give a clear picture. I show a drawing of part of what I have described, as I have done with the drawings in the other chapters, split into its separate parts.[41]

Al-Jazari's schematic drawings, like the ones included in *girih* scrolls, would have to be translated into full-scale templates and were capable of communicating the basic information necessary for artisans already equipped with empirical workshop experience. It is not a coincidence that al-Jazari compared his metalwork door to joined woodwork, the so-called *Kassettenstil* (Persian, *kunda-kārī,* "tongue-and-groove jointing"), in which precious pieces of wood and mother-of-pearl cut in polygon and star shapes were intricately fitted together. This technique no doubt required a grounding in practical geometry, as is confirmed by the example of Abu al-Fadl b. ᶜAbd al-Karim al-Muhandis (d. 1202–1203), the carpenter and stonemason responsible for making the doors of the Ayyubid ruler al-Malik al-ᶜAdil's hospital in Damascus, who had studied Euclid to acquire excellence in the geometric art of wood joinery. Ibn Khaldun confirmed that carpenters had to be trained in practical geometry, just like architect-engineers who used it in designing buildings and instruments (constructed according to geometric proportions) for lifting water and for moving heavy loads of building materials.[42] He wrote:

> In view of its origin, carpentry needs a good deal of geometry of all kinds. It requires either a general or a specialized knowledge of proportion and measurement, in order to bring the forms [of things] from potentiality into actuality in the proper manner, and for the knowledge of proportions one must have recourse to the geometrician. Therefore, the leading Greek geometricians were all master carpenters. Euclid, the author of the *Book of the Principles,* on geometry, was a carpenter and was known as such. The same was the case with Apollonius, the author of the book on *Conic Sections,* and Menelaus, and others.[43]

Ibn Khaldun was repeating a tradition, whose origin has not yet been explained, that linked these two famous geometers of the Alexandrian school with the vocation of carpentry. In several biographical sources both Euclid and Apollonius of Perga appear with the epithet "the carpenter" (*al-najjār*), an epithet that may simply have reflected contemporary Islamic craft practices.[44]

Caᶜfer's *Risāle-i Miᶜmāriyye,* which discusses the career of the Ottoman architect Mehmed, shows that practical geometry (*handasa*) and mensuration (*misāḥa,* the science of measurement dealing with lengths, surfaces, and volumes of geometric figures) continued to play a central role in the training of architects and carpenters in the early modern era. This treatise includes a substantial section on the science of geometry, identified as the common basis for the crafts of architecture, mother-of-pearl-inlaid woodwork, and music, in all of which Mehmed was trained during his apprenticeship at the royal workshops of the Topkapı Palace's outer garden. The author traced the origins of this science to the philosopher Pythagoras who "collected both the science of geometry and the science of mathematics into a book." It was also Pythagoras who had systematized the science of music: "He discovered, arranged and classified rhythmic patterns from the crashing of the waves of the sea."[45]

An episode recounted in the *Risāle* shows that manuscripts of practical geometry were used to educate apprentices in the craft workshops of the Topkapı Palace. It describes how a youth read a book of geometry aloud in the workshop of the

mother-of-pearl workers: "As he read each section, he would turn and narrate and explain it to them. By chance, the book which he was reading was about the science of geometry."[46] When Mehmed (apprenticed at that time to the neighboring workshop of musicians) heard "the intelligent youth . . . reading the book which thus described geometry and architecture," he decided to switch to the study of the "arts of working of mother-of-pearl and of architecture." After demonstrating his skill by striking a plank with an adz on a marked spot, he was accepted into the brotherhood to learn these two arts, upon which the young man reading the book said: "If this boy turns toward this art with this skill, let me also teach him the science of geometry, and transcribe and present him with a copy of the book in my hand so that as long as he lives he will have in his hands a token from me."[47] This episode confirms that "how-to" manuals of applied geometry continued to be used by literate master masons and master craftsmen while the information contained in them was orally transmitted to apprentices as part of their workshop training.

The *Risāle* asserted that "as long as a person does not understand this rare and agreeable science [i.e., geometry], he is not capable of the finest working in mother-of-pearl, nor can he be an expert skilled in the art of architecture."[48] Caᶜfer himself compiled a treatise of practical geometry based on the discussions he had overheard while he was in the service of Mehmed during the latter's tenure as chief court architect (1606–1618): "Because we have been connected with him for many years until the present time, for the most part closely, when certain subjects concerning the science of geometry were being discussed, this humble servant took and wrote down everything. In accordance with this, he set down and composed a treatise concerning the science of geometry."[49]

Unfortunately Caᶜfer's treatise has not yet surfaced, but its contents dealing with practical geometry can be surmised from the brief chapter on the same subject he included in the *Risāle,* which refers to modular cubit measures, geometric methods of mensuration used in land surveying, and geometric figures used "above all in the art of mother-of-pearl working." It is clear that he was not concerned with theoretical geometry and its proofs but with a practical geometry based on a knowledge of basic figures and their properties. He wrote: "Now, in the science of geometry there are several forms. When these are mastered, the rest is easy." He identified these as the circle, semicircle, small arc of the circle lesser than the semicircle, large arc of the circle bigger than the semicircle, triangular forms, quadrangles, pentagons, hexagons, heptagons, octagons, nonagons, decagons, and so on and added, "The art of mother-of-pearl inlay makes use only of forms derived from the science of geometry."[50]

Mehmed's mastery in manipulating geometric forms in the craft of mother-of-pearl-inlaid carpentry culminated in architectural works when he became the chief architect of the Ottoman court. The Sultan Ahmed mosque he built in Istanbul is described in the *Risāle* as a wonder of geometry:

> Because it is not possible to relate how vast a building this noble mosque is, how solidly its foundations and structure were made, we have not described these. In truth, one who wishes to understand these matters should first become greatly skilled and well versed in the science of geometry. After that, it is necessary to study and ponder it for many days and months and years and for much time in order to comprehend in what manner and in what ways its various designs and interlocking decorations were put together.[51]

Mehmed had not only studied at the Topkapı Palace's imperial garden under a master carpenter and various journeymen (*ḫalīfe*) but also under the renowned Ottoman chief architect Sinan who often came there while he occupied that post between 1538 and 1588: "And each time the Great Architect came to the Imperial Gardens, he [Mehmed] studied the science of geometry and the art of architecture with him and others."[52]

Sinan's role as a teacher is also implied in his endowment deed (*waqfiyya*), which refers to him as "the royal professor" (*muᶜallim-i ḫāḳānī*); his mastery in geometry is expressed in the same source by his title "Euclidius of the Age."[53] Sinan, too, was initially trained by a master carpenter in the craft of carpentry (*neccār*), which introduced him through the use of ruler (*hencār*) and compass (*pergār*) to geometry, the groundwork of architecture. In the autobiography he dictated to Saᶜi, Sinan thanked his master for training him in the

craft of carpentry and then poetically described his apprenticeship period:

> Remaining in the service of my master like a compass with one leg fixed, I turned my attention to center and circumference [i.e., drawing circles]. Then, just as a compass draws an arc, so I desired to tour countries. For a while in the service of the sultan [Selim I] I cruised the Arab and Persian lands, deriving my food from the pinnacle of each iwan, and my lodging from the corner of each ruin.[54]

That Sinan's mosques were seen in the Ottoman world as masterpieces of applied geometry is captured in a description of the Süleymaniye mosque (1550–1557) by the seventeenth-century traveler Evliya Çelebi who put the following words into the mouth of a European architectural expert distinguished in the science of geometry: "Both the interior and exterior of this mosque have been built in a charming manner; in the whole of Frankistan [Europe] we did not see such an exemplary building perfect in terms of the science of geometry [*ʿilm-i hendese*]." The prestige of geometry in Ottoman architectural practice is also reflected in the late sixteenth-century court historian Lokman b. Seyyid Hüseyin's account of the guild processions in Istanbul during a royal circumcision ceremony in 1582. Here, an unnamed skilled architect (*miʿmār*) and engineer (*mühendis*) who prepared a painted and gilded three-dimensional model of the Süleymaniye mosque for the parade is praised for his Euclid-like mastery of geometry and his ability to reproduce the universe and the vault of the heavens in his imaginative designs (*ṭarḥ*) drawn with compasses. That this architect-engineer was most likely Sinan himself can be deduced from a later procession of guilds during the circumcision festivities of 1675 for which the chief royal architect (*miʿmār aġa*) had prepared two models of kiosks placed in gardens with jets of water; these were paraded in front of the sultan on separate wheel-carts.[55]

Sinan was perpetuating the Romano-Byzantine tradition of military architect-engineers that the Ottomans had filtered through the prism of their own architectural heritage and new influences from Renaissance Italy. Early in his career he participated in various building projects in addition to constructing wooden warships, fortresses, and bridges that prepared him for the masterpieces he would create as chief royal architect. In those years he continued to build bridges, aqueducts, and water channels, projects that occupy as important a place in the architect's autobiography as religious and secular monuments. Like his successors Davud (d. 1599), Dalgıç Ahmed (d. 1608), and Mehmed, who had first served as superintendents of waterworks (*ṣuyolı nāẓırı*) before they were promoted to the office of chief architect, Sinan was deeply involved with hydraulic engineering. His career, therefore, is in keeping with the traditional Islamic classification of architecture as a subfield of applied mechanics, a classification that explains why the lost architectural treatises of Ibn al-Haytham and al-Karaji included sections on the construction of fortifications, bridges, dams, and irrigation works.

As chief royal architect, Sinan occupied the highest bureaucratic position in the centrally organized Ottoman construction industry, where master masons, masons, and the practitioners of various building-related crafts (including carpenters and the ceramic tile makers of Iznik) were directly placed under his supervision. The relatively high social status of Ottoman master masons (*üstād*) can be deduced from Lokman's description of their guild procession in 1582 when they were accompanied by ordinary masons (*bennā*). While the latter paraded with their working tools and cubit measures (*arşūn*), the masters proudly marched empty-handed, wearing expensive silk brocade caftans (*kemḫā ve serāser*) and large turbans. They went about giving firmanlike orders to construction workers (*ırġād*), "not one of them being involved in manual labor [*el işçisi*]" himself. These master masons, "who had never even driven a nail" refused to be ordered around and would not listen to any command "even if one were to drive it into their ears with a screw." Sinan, who held a major administrative post, enjoyed even greater prestige than the master masons under his command. Nevertheless, his image differed from that of his contemporaries in Renaissance Italy where the subordination of architecture to mechanics was renounced to such a degree that "in many parts of Italy a man is called a mechanic in

scorn and degradation, and in some places people are offended even to be called engineer."[56]

The similar geometric basis of the training of architect-engineers in Mughal India is documented in written sources that often refer to them as Euclid-like skilled geometers.[57] For example, the architect Ustad Ahmad Lahori (d. 1649), who participated in the construction of the Taj Mahal, was at once a skilled engineer and learned in the sciences of geometry, arithmetic, and astronomy. This architect, who received the title "Wonder of the Age" from his patron Shah Jahan, is described in a collection of poems by his son Lutf Allah Muhandis as acquainted with Euclid's *Elements* and with the second-century astronomer and mathematician Ptolemy's *Almagest*, through which the mysterious "movements of the planets and stars had become known to him."[58] Ahmad Lahori had descended from a family of Timurid architects originating in Herat; his two sons and grandsons also followed the profession of their forefathers. Lutf Allah, who used the pen name Muhandis, was an architect-engineer and mathematician who composed a practical treatise on arithmetic filled with geometric diagrams. Ahmad Lahori's other son, ᶜAta' Allah, also wrote several practice-oriented treatises on the mathematical sciences and translated a Sanskrit text on algebra into Persian for Shah Jahan in 1634–1635.[59] He, too, was an architect and built the Mughal queen Rabiᶜa al-Dawrani's (d. 1657) tomb at Awrangabad, modeled on the Taj Mahal. The family profession was perpetuated by yet another generation with Lutf Allah's son Khayr Allah who composed in 1731 a practical mathematical treatise containing geometric diagrams.[60]

This family of architects practicing in Mughal India appears to have perpetuated a late Timurid tradition—to which the Topkapı scroll belongs—enriching it with local contributions. Ahmad Lahori's mastery of the "secrets" of the *Almagest* recalls a description of the fifteenth-century Timurid architect Ustad Qawam al-Din Shirazi as "the greatest architect of the age" who was also an "expert at astronomy." The latter had presented an ephemeris as a gift to the Timurid ruler Shahrukh, upon which his patron allegedly recited the following line of poetry: "You did the work of the earth so well that you took up the heavens too."[61] These two architects' preoccupation with astronomy reflects the dynamic interchange between the various branches of the quadrivium. It also testifies to the persistence of the ideal image of the architect cultivated in Persian literature, which was permeated with ancient Near Eastern mythology and frequent allusions to the astrological secrets commanded by architects and artisans.

Nizami's *Haft Paykar* (Seven portraits), for example, describes the learned architect, who built for the Sasanian prince Bahram Gur (r. A.D. 420–438) a seven-domed palace reproducing the structure of the heavens, as possessing an outstanding knowledge of geometry, astronomy, medicine, calligraphy, and painting. Similarly Nizami's *Khusraw wa Shīrīn* describes the legendary sculptor Farhad as a master of geometry who surpassed Euclid and studied the *Almagest* before taking up the chisel. These two popular romantic epics would inspire new versions, including the ones written by the Indo-Muslim poet Amir Khusraw Dihlawi (1253–1325) and by the late Timurid poets Jami and Nawa'i, where the same image of the ideal architect is encountered. The thirteenth-century architect Badr al-Din Tabrizi, who built the tomb of Mawlana Jalal al-Din Rumi in Seljuq Konya, is described in similar terms; he possessed a knowledge of the sciences of astronomy and mathematics besides alchemy, chemistry, and philosophy.[62] These no doubt idealized literary descriptions echo Pappus of Alexandria's and Vitruvius's accounts of the ideal curriculum of the architect or *mechanicus*.

Vitruvius's definition of the well-rounded architect's background also encompassed a knowledge of many sciences, including astronomy, used in orienting buildings and constructing sundials: "Let him be educated, skillful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of jurists, and be acquainted with astronomy and the theory of the heavens."[63] Vitruvius qualified his statement by admitting that since it is impossible to be an expert in all these fields, a modest knowledge of their practical principles would suffice for the architect:

> For in the midst of all this great variety of subjects, an individual cannot attain

> to perfection in each, because it is scarcely in his power to take in and comprehend the general theories of them. . . . As for men upon whom nature has bestowed so much ingenuity, acuteness, and memory that they are able to have a thorough knowledge of geometry, astronomy, music and the other arts, they go beyond the functions of architects and become pure mathematicians.[64]

Scientist-architects, such as the professional mathematicians Isidorus of Miletus; Anthemius of Tralles; Gabriele Stornaloco, who was called in during the planning of the Milan cathedral in 1391; and Sir Christopher Wren (1632–1723), who was a professor of astronomy at Oxford, have been the exception rather than the rule in the history of Western architecture. This was also the case in the Islamic world, except for such rare examples as Baha' al-Din ᶜAmili (1564–1621), the remarkable Safavid theologian who was not only an accomplished architect but also known for his dozens of works on various branches of the mathematical sciences, including astronomy, arithmetic, and irrigation. Theoretically sophisticated early medieval mathematicians such as the Banu Musa brothers, Ibn al-Haytham, and al-Karaji did get involved in construction projects such as building dams, digging irrigation channels, laying out new cities, and advising builders, but the more common breed of architect-engineers with a working knowledge of practical geometry and applied mechanics rarely included distinguished scientists.[65]

Qawam al-Din Shirazi and the members of Ahmad Lahori's family were literate and did possess a well-rounded knowledge of the various branches of the mathematical sciences, but their knowledge in these fields appears to have been largely practical rather than theoretical. The level of arithmetic knowledge commanded by Timurid architects, however, remains controversial. Bulatov, for example, argued that Central Asian master builders had a considerable knowledge of advanced computation and trigonometry up to the end of the Timurid era. Others, such as Rempel' and Pugachenkova, have regarded Central Asian architects as highly qualified master builders who did not necessarily comprehend the theoretical or numerical bases of the practical geometry they so skillfully used. While Rempel' and Pugachenkova based their conclusions on the graphic methods reflected in the geometric drawings of the Tashkent scrolls, Bulatov saw the existence of treatises on applied arithmetic by such mathematicians as Muhammad b. Musa al-Khwarezmi, al-Buzjani, and al-Kashi (which contain architectural references) as evidence for a deeper knowledge of arithmetic computation among architects.[66]

To resolve this controversy we must turn to the contents of Islamic manuals on practical arithmetic and assess whether they would have been useful for the purposes of designing architects. Their earliest surviving example was written in ninth-century Baghdad by the mathematician and astronomer al-Khwarezmi, attached to al-Ma'mun's *Bayt al-ḥikma*. In the words of its author, this work was confined to "what is easiest and most useful in arithmetic, such as men constantly require in cases of inheritance, legacies, partition, lawsuits, and trade, and in all their dealings with one another, or where the measuring of lands, the digging of canals, geometrical computations, and other objects of various sorts and kinds are concerned." The treatise's first part, dealing with problems arising from the division of inheritances and trade, involves only arithmetic and linear equations. Its shorter second part addresses the practical applications of mensuration (*misāḥa*), that is, the approximate calculation of the areas of various plane and solid geometric figures by cubit measures: "Know that the meaning of the expression *one by one* is mensuration: one cubit [*dhirāᶜ*] [in length] by one cubit [in width]." Here rules are given to find the areas of such figures as the circle, cone, cylinder, pyramid, and truncated pyramid. That practical mensuration is only concerned with simplified formulas becomes apparent in the three different pi values al-Khwarezmi provided for calculating the circle, one used in "practical life, though it is not quite exact," and the other two used by geometers and astronomers.[67]

The second part of al-Khwarezmi's treatise applied algebra (which involves both arithmetic and geometric proofs) to geometric problems, an area where the mathematicians of the Islamic

world are known to have outstripped their Greek and Indian counterparts. The use of algebra in geometry and the solution of algebraic problems with the aid of geometry would be explored by many Arabic-writing mathematicians. For example, one of the earliest Muslim algebraists who lived in the second half of the ninth century, Abu Kamil Shujaᶜ, wrote a mensuration treatise on the pentagon and decagon that solved problems by applying algebraic methods to geometry. Since Islamic encyclopedias consistently define architecture and practical mechanics as branches of applied geometry, the geometric proofs of algebra were directly relevant to these fields. Al-Buzjani's late tenth-century manual on applied arithmetic entitled *Kitāb al-manāzil fīmā yaḥtāju ilayhi al-kuttāb wa al-ᶜummāl min ᶜilm al-ḥisāb* (Book of the stations on what the scribe and secretary needs of the science of arithmetic) contains chapters on practical geometry that extend al-Khwarezmi's application of algebra to geometric problems into new fields. Its first two parts deal with simple arithmetic operations (e.g., ratio, multiplication, and division). Its third part applies these operations to the mensuration of plane and solid geometric figures, including the spherical or conical dome (*qubba*). The remaining four parts address such practical problems as the payment of work, taxation, inheritance apportionments, shares related to harvest, exchange of currency, commercial transactions, and construction estimates for buildings and dams. The last section contains calculations of wages for mortaring and bricklaying, as well as of streams filling a well.[68]

Unlike al-Buzjani's manual on practical geometry, which addresses the practitioners of various crafts, this one on applied arithmetic reflects the concerns of scribes and secretaries, as its title implies. The use of arithmetic in land surveying, in making correct estimates of building costs, and in the digging of irrigation channels belonged to the realm of expertise required from the well-rounded secretary. Ibn Qutayba (825–889), the polygraph who was both a theologian and a writer of *adab* (the sum of knowledge necessary for general culture and for particular offices), described the skills that the perfect secretary should possess:

> The Persians always used to say, "He who is not knowledgeable about diverting water into channels, digging out courses for irrigation streams, and blocking up disused well-shafts; about the changes in the length of the days as they increase and decrease, the revolution of the sun, the rising places of the stars and the state of the new moon as it begins to wax, and its subsequent phases; about the various weights in use; about the measurement of triangles, four-sided figures and polygons; about the construction of bridges and aqueducts, irrigation machines and water wheels; and about the materials used by various artisans, and the fine points of financial accounting—such a person must be considered only partly-qualified as a secretary."[69]

In addition to boasting linguistic, calligraphic, and literary skills, then, the ideal secretary and administrator (whose urbane culture of "polite learning" was reflected in the literary genre of *adab*) was expected to have some practical competence in mathematics to deal with accounting, taxation, inheritances, cadastral surveys, and measuring allocations of water in irrigation channels (a major function of the state in the irrigated oases of Iran, Iraq, and Central Asia).

The extensive knowledge of applied mathematics in Buyid Baghdad, where the main bearers of humanistic culture were the scribes, secretaries, literati, and high officials of state chancelleries and courts, can be deduced from the biographies of such personages as the vizier Ibn ᶜAbbad (d. 995), who was devoted to studying logic, mathematics, music, astronomy, and medicine. The vizier Ibn al-ᶜAmid's mastery of the mathematical sciences was described by the contemporary philosopher and historian Ibn Miskawayh:

> He was sole master of the secrets of certain obscure sciences which no one professes, such as mechanics, requiring the most abstruse knowledge of geometry, and physics, the science of abnormal motions, the dragging of heavy weights,

> and the centers of gravity, including the execution of many operations which the ancients found impossible, the fabrication of wonderful engines for the storming of fortresses, stratagems against strongholds and stratagems in campaigns, the adoption of wonderful weapons, such as arrows which could permeate a vast space, and produce remarkable effects, mirrors which burned a very long way off. He could, for his amusement, scratch the form of a face on an apple in an hour—a face so fine that another could not do it with all the appropriate instruments in a number of days.[70]

These references explain why al-Buzjani's treatise on applied arithmetic addresses the bureaucratic concerns of scribes, secretaries, and accountants. The use of arithmetic in making correct estimates of building costs and wages was a task often assigned to clerks responsible for the administrative and financial aspects of construction projects. The division of labor between such bureaucratic overseers and designing architects responsible for construction is better documented from the Ilkhanid period onward, even though in some instances architects were also charged with administrative tasks. The Timurids, for example, generally differentiated administrative superintendents (*sarkārhā* or *sarkārān*) from architects (*miᶜmārān* or *ustādān*), just as the Ottomans distinguished between the building supervisor (*binā' emīni*) and the architect (*miᶜmār*). Similarly in Mughal India it was the chief building supervisor (*mīr ᶜimārat*) who had to be "versed in accountancy or alternatively, employ an accountant" to ascertain the number of stones or bricks required according to fixed units of measurement, to determine the builder's wages, and to know the prices of building materials.[71] Therefore, practical manuals on arithmetic seem to have been more useful for the concerns of building supervisors than for architects whose design methods primarily relied on geometry. There were, of course, some examples of architects who were both skilled in arithmetic and capable of acting in an administrative capacity as building supervisors, but such skills were of little relevance for the processes of architectural design.

Following the example set by al-Khwarezmi and al-Buzjani, such early eleventh-century mathematicians as al-Karaji and Ibn al-Haytham continued to include chapters on mensuration in their treatises on applied arithmetic. These were complemented by full-scale treatises on the science of mensuration (*ᶜilm al-misāḥa*), classified as part of practical geometry.[72] Mensuration treatises often proceed from the measurement of lines and planimetry (mensuration of surfaces) to stereometry (mensuration of solids), some of them concluding with practical applications in hydraulic engineering, land surveying, and architecture. The latter address such problems as the indirect measurement of mountains and distant objects and the calculation of the depth of wells, the breadth of rivers, the height of walls, and the number of stones or bricks required to build a monument or a dome.

Their relatively short architectural sections dealing with the mensuration of arched (*ṭīqān*), vaulted (*āzāj*), and domed (*qubba*) halls may have been inspired by Hero of Alexandria's now-lost first-century treatise on stereometry entitled *Kamarika* (On vaultings). Hero's treatise, on which Isidorus of Miletus wrote a commentary, included practical formulas for calculating the surfaces of arches, columns, vaults, domes, and other architectonic structures. It may have influenced al-Kindi's lost ninth-century work on the same subject, *Risāla fī misāḥat īwān* (Treatise on the mensuration of vaulted halls [*iwans*]), which is cited in Ibn al-Nadim's *Fihrist* and described in Daniele Barbaro's sixteenth-century commentary on Vitruvius as a work devoted to the geometric, arithmetic, and harmonic proportions used in calculating the heights and surface areas of vaulted chambers.[73] As we have already seen, several mathematicians including Thabit b. Qurra and al-Sijzi had written similar treatises on the mensuration of parabolic domes (see figs. 103–106).

An undated example of practice-oriented mensuration manuals is that written by an otherwise unknown geometer Abu Bakr (Abhabuchr), translated from Arabic into Latin in an abridged form by the Italian scholar Gerard of Cremona (1114–1182) in Toledo as *Liber mensurationum* (Book of mensuration). The Latin text gives "how-to" instructions in a simple language without attempting to provide proofs and its practical formulas

provide approximative results typical of practical geometry. Consisting of four parts, it starts with procedures for calculating the surfaces of quadrangles (treated as triangles), triangles, and the arcs of circles, providing tabulated tables that facilitate the computation of the most important lengths of these figures. It then turns to the mensuration of volumes, including roof shapes. Referring to the *Liber mensurationum,* a treatise that appears to have been widely disseminated in medieval Europe, Hubert L. L. Busard pointed out that it is characterized by the frequent application of algebra to problems of practical geometry, a method he traced back to ancient Babylonian algebra and to Hero of Alexandria.[74] These influences seem to have been transmitted through Harran, the center of mathematical learning where ancient Near Eastern and Hellenistic cultures merged.

The Timurid astronomer and mathematician al-Kashi's treatise *Miftāḥ al-ḥisāb* also includes an extensive chapter on mensuration, dealing with the areas of plane and solid geometric figures after which it treats architectonic structures. This well-known treatise, dedicated in 1427 to the Timurid ruler Ulugh Beg, who had invited al-Kashi in 1419 from the Qaraqoyunlu city of Kashan to Samarqand, is usually taken as evidence for the Timurid-Turkmen architects' expertise in advanced arithmetic computation. The treatise's fourth book on mensuration ends with a chapter on measuring architectonic structures such as arches (*ṭāq*), vaults (*āzāj*), domes (*qubba*), and muqarnas types. As al-Kashi indicated, this chapter is more detailed than earlier examples on the same subject where the muqarnas had been omitted: "The specialists merely spoke about this [i.e., measuring] for the arch (*ṭāq*) and the vault (*āzāj*) and besides that it was not thought necessary. But I present it [i.e., the muqarnas] among the necessities together with the rest, because it is more often required in the mensuration of buildings than in the rest."[75]

Rather than present instructions on how to design architectonic structures, al-Kashi taught the method for calculating their surface area by means of approximate values. He appears to have been concerned mainly with determining the amount of material required, a concern that may reflect his experience as building supervisor during the construction of Ulugh Beg's observatory in Samarqand. This hypothesis finds support in a letter he addressed to his father in Kashan, in which he reported that nearly five hundred *tūmāns* worth of brick and limestone had been spent by the time the head mason Ismaᶜil had almost finished the observatory.[76]

In her recent articles providing modern mathematical analyses of al-Kashi's formulas for the mensuration of the dome and the muqarnas, Yvonne Dold-Samplonius reached a similar conclusion about the author's purpose: "In medieval Italy it was common practice to pay the craftsmen or artisans according to the surface area they had completed. The same custom may have existed in the Arab world. It is also useful to know, more or less, how much material is needed, like gold for gilding, bricks for construction or paint and such things."[77] We know, for example, that payment per cubit was common in Ottoman architectural practice where a team of architects and surveyors had to make cost estimates (*keşf* or *taḫmīn*) of projected buildings and supply preliminary drawings for various options (see fig. 2). In addition to facilitating estimates of wages and building materials before construction, al-Kashi's formulas may also have been used in appraising the price of a building after its completion. As we have already seen, the traveler Chardin reported that the chief royal architect in Safavid Iran determined the value of completed buildings by measuring their walls in cubits, a value on the basis of which he was paid a fixed percentage.[78]

Linda Komaroff has argued that al-Kashi's treatise "was almost certainly intended for his fellow mathematicians, rather than for architects and craftsmen." She found it unlikely that the treatise was written for the use of contemporary builders since its author "often distinguishes between the terms we use—presumably mathematicians—and the terminology of the mason or the carpenter, a clear indication that he was not addressing his remarks to the practitioners of the builder's craft." It is therefore revealing that al-Kashi referred to practical working methods in his discussion of the "mason's method" of constructing the muqarnas, which differs from the method of mathematicians. Here he used a technical drawing to describe how the masons draw a rectangle whose width equals the module (*miqyās*) of the muqarnas and whose length is twice its width. After showing how the

profile of a modular muqarnas unit is determined, al-Kashi went on to explain how builders cast individual units in slabs of plaster, adjusting them to a given arch profile, "and at times they shorten the leg of the slab . . . or they elongate it so that whenever they place it behind the arch they would need that [elongation or shortening] so that it will match with it" (see ill. 2, p. 353).[79]

After this explanation, which provides a rare insight into how muqarnas units were actually prepared by builders on the basis of geometric (rather than arithmetic) methods, al-Kashi computed an average coefficient to approximately calculate the areas of curved muqarnas formations. In his discussion of arches, too, he first drew them with ruler and compasses according to prevailing geometric formulas and subsequently converted them into numbers. In other words, al-Kashi's approximate numerical values are derived from architectural forms that were generated by masons according to the methods of practical geometry rather than the other way around. It was not on arithmetic computation but on a series of geometrically proportioned working drawings that the design process of practicing Timurid-Turkmen masons was based, a conclusion also supported by the Topkapı and Tashkent scrolls.

Vitruvius wrote, "It is true that it is by arithmetic that the total cost of buildings is calculated and measurements are computed, but difficult questions involving symmetry are solved by means of geometrical theories and methods." Geometry, he observed, "teaches us the use of the rule and compasses, by which especially we acquire readiness in making plans for buildings."[80] The ready-made tabulated tables provided in al-Kashi's treatise made computation easier for building overseers. Although they were of little use in the designing process, they must also have been used by architect-engineers whenever they required the help of arithmetic, whether in preparing cost estimates, in calculating measurements, or in computations related to hydraulics. Unlike professional mathematicians skilled in advanced computational mathematics, architects in the late Timurid world would have needed only a basic knowledge of simple arithmetic operations, accompanied by a much more solid grounding in practical geometry. This conclusion seems valid for architectural practice in the early modern Islamic world as well, judging from the Ottoman, Safavid, Uzbek, and Mughal evidence. An archival document that compiles information about various aspects of the Ottoman construction industry in the 1770s, including standardized costs of building materials, petitions from the chief architect to the sultan, and "how-to" instructions for practical problems of mensuration (*mesāḥa*), further supports such a conclusion. Here, problems dealing with computing the areas of circles, domes, and columns; determining the height of a minaret from a distance; and calculating amounts of building materials required for specific projects are all solved by means of simple arithmetic formulas providing approximate results. The reference to a formula by "Ghiyath al-Din Jamshid" in this document shows that al-Kashi's treatise, of which numerous Turkish translations exist, continued to be used in the Ottoman world.[81]

In his seventeenth-century treatise *Breve compendio de la carpintería de lo blanco y tratado de alarifes,* which heavily drew on earlier Islamic practices, López de Arenas pointed out that, unlike the master mason (*maestro*), the chief architect (*alarife*) had to combine experience (*experiencia*) and science (*ciencia*), including a knowledge of reading, writing, and enough arithmetic to determine taxes and sale prices. Much more important than these, however, was a training in practical geometry, based on the manipulation of polygonal geometric constructions drawn with the aid of basic tools such as the ruler, set squares, and the compass with a single opening (thought to have been used for the first time by al-Buzjani). López de Arenas's practical geometry manual was written in a highly specialized technical language full of obscure Arabic terms and accompanied by two- and three-dimensional geometric drawings recording the traditional working methods of Muslim masters that were perpetuated in the Mudejar style (see figs. 51, 52). The manual addressed practitioners at a time when inherited geometric formulas that required no arithmetic were being forgotten. New Renaissance tastes gained favor and the medieval guild system was being replaced by professional architects. López de Arenas, therefore, wanted to

preserve for posterity the traditional rules he had inherited from his father and uncle. Whereas his forebears must have jealously guarded their craft secrets in practical geometry manuals and scrolls passed on from one generation to the other, López de Arenas utilized the new medium of the printing press.[82]

Unlike their Renaissance colleagues in Europe, who were rapidly abandoning geometry in favor of precisely measured drawings based on numerical proportions, architects in the early modern Islamic world remained loyal to Pappus of Alexandria's definition of architecture as a branch of practical mechanics. Even though the importance of geometry prevailed in Europe, Renaissance theorists increasingly divorced architecture from its earlier subordination to mechanics in an attempt to assert its independence and higher status as a liberal art. Fortifications, hydraulics, and instruments thus came to be seen as specialized subfields of mechanical engineering. By contrast architects in the Islamic world continued to uphold the ideal image of the well-rounded *mechanicus* (*muhandis*) whose mental universe was colored by practical geometry, with its still-prestigious connection to the liberal art of mathematics.[83]

Before the Renaissance, however, architectural design in both the Latin West and in the Islamic world had been grounded in similar geometric methods requiring little arithmetic. Although medieval Europe did not have access to Euclid's geometry until the twelfth century, by the middle of the thirteenth century advances in the mathematical sciences had contributed to the development of dynamic systems of geometric design, based on a type of rotational geometry not unlike the one developed in the Islamic world around the tenth and eleventh centuries. Since standard geometric approaches united the various crafts, practical geometry came to act as a kind of shared aesthetic theory with its own formal logic that guided systems of proportioning across different fields in Gothic architectural and artisanal practice.[84]

This development was no doubt informed by the assimilation of translated Arabic treatises on practical geometry, in addition to the recovery of major classical texts through Arabic intermediaries. The similarity between Gerard of Cremona's twelfth-century Latin translation of Abu Bakr's treatise on applied mensuration, *Liber mensurationum*, and the Spanish mathematician Abraham bar Hiyya's (Savasorda or Abraham Judaeus, fl. 1133–1145) work on the same subject shows how rapidly practice-oriented mensuration manuals by Muslim authors had infiltrated medieval Europe. Abraham bar Hiyya's Hebrew treatise *Ḥibbūr ha-meshīḥah*, translated by Plato of Tivoli in 1145 into Latin as *Liber embadorum* (Book of areas), was in fact an expanded version of the second part of al-Khwarezmi's mathematical treatise that applied algebra to mensuration. Together with Abu Bakr's treatise, it is believed to have been among the unknown sources of the thirteenth-century mathematician Leonardo Fibonacci of Pisa's *Practica geometriae,* 1220, which remained the standard work on that subject for three centuries.[85] Gustavo Sacerdote and Heinrich Suter have argued that the Pisan geometer also used Abu Kamil's algebra and his shorter treatise on the pentagon and decagon, available through Latin and Hebrew translations made in Spain. Woepcke has suggested that the practical geometry of al-Buzjani must also have been among Fibonacci's sources.[86]

Whatever the transmission patterns of Greek and Arabic learning may have been, the parallels between medieval European practical geometry manuals and their Islamic counterparts are striking. This was largely the outcome of a shared classical heritage that reached medieval Europe through translations of Arabic intermediaries that did not merely "transmit" Greek originals but often transformed them in hitherto unknown directions promising practical application in a number of fields. The translation of Arabic scientific and philosophical works, which began in tenth-century Norman Sicily and flourished during the twelfth century in Spain (particularly around Toledo after it fell in 1085), became a Europe-wide phenomenon that triggered as great a cultural change as did the earlier translation movement in Abbasid Baghdad. Especially in Spain this activity reached such an uncontrollable extent that the sale of scientific books to Jews and Christians is prohibited in a treatise on *ḥisba*

(the duties of an inspector of the marketplace) written by the Spanish author Ibn ᶜAbdūn in early twelfth-century Seville. The treatise indicates that this measure was taken because the translators often attributed the works they had translated to themselves, without crediting their original Muslim authors.[87]

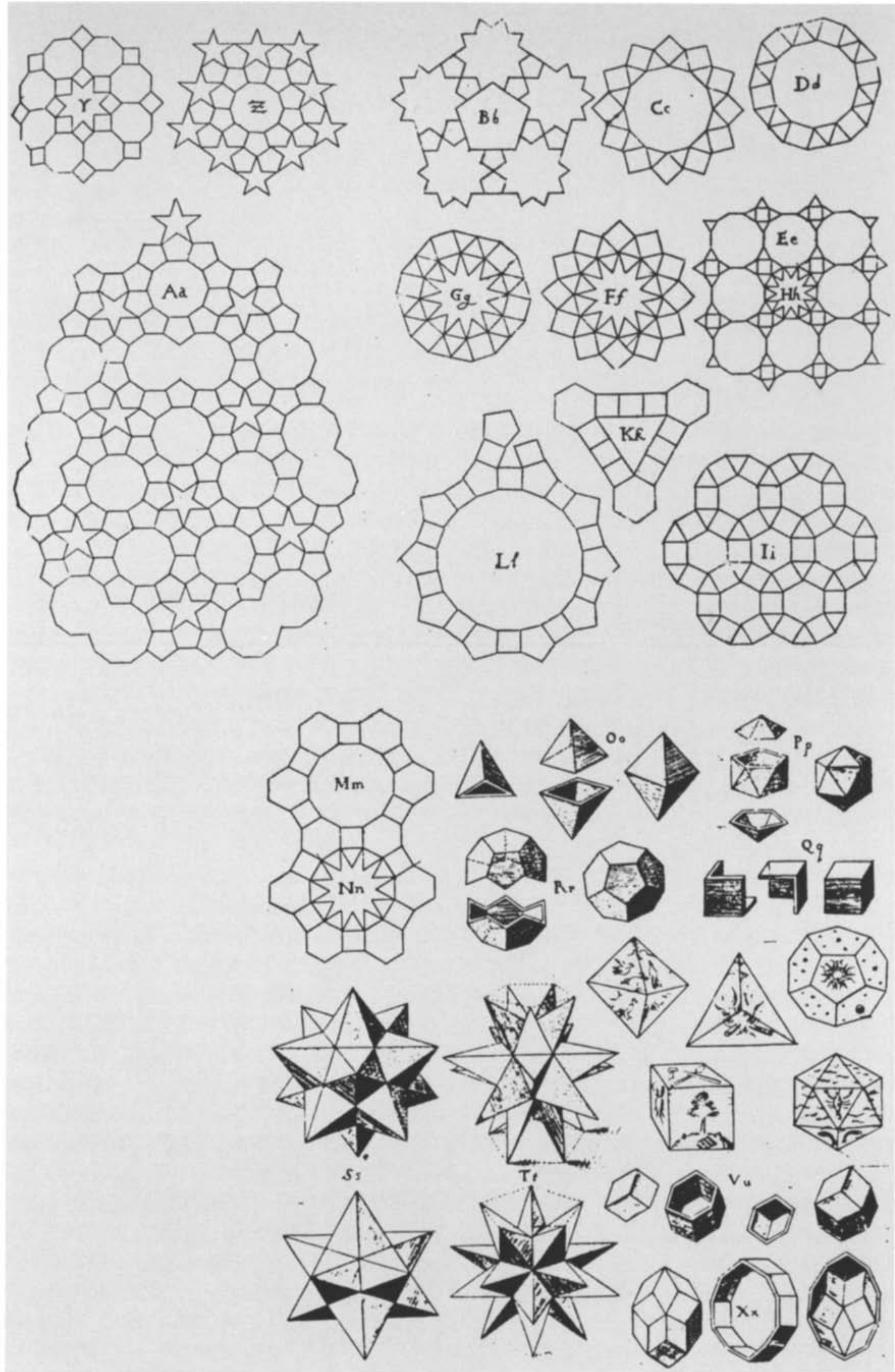
Even the definition of geometry in the Arab classifications of sciences was fully adopted by such twelfth-century authors as the Spaniard Dominicus Gundissalinus (Domingo Gundisalvo), who emphasized its practical application in various fields.[88] Gundissalinus's classification of the sciences, *De ortu scientiarum,* circa 1150, which stressed the complementary nature of theory and practice, drew heavily on al-Farabi's tenth-century *Iḥṣā',* which had been translated into Latin as *De scientiis* by Gerard of Cremona in Toledo. Following al-Farabi's model, Gundissalinus enlarged the medieval European domain of practical geometry to include masonry, carpentry, metalwork, mensuration, and the construction of machines and instruments, including those of optics.

> The agent of practical geometry is he who employs it in working. There are, however, two classes who employ it in working, measurers and makers. The measurers are those who measure the height, depth or surface area of the earth. The makers are those who toil in working in the mechanical arts, as a carpenter in wood, a blacksmith in iron, a mason in cement and stones, and similarly every agent of the mechanical arts following practical geometry.[89]

This definition revived a tradition going back to classical antiquity with its emphasis on the intellectual or theoretical nature of certain crafts intimately linked to the mathematical sciences. It endowed the crafts with a much higher status than the alternative and apparently more widespread medieval European definition proposed in the theologian Hugh of Saint Victor's (1096–1141) encyclopedic *Didascalion,* written in the 1120s, where the seven mechanical arts (fabric making, armament [encompassing architecture and the crafts], commerce, agriculture, hunting, medicine, and theatrics) were classified as entirely separate from theoretical knowledge. Hugh's classification eliminated the possibility of contact between the "servile" realm of the mechanical arts and the liberal arts, among which the purely theoretical science of mathematics was included. By contrast the classical connection between these two realms was perpetuated without any rupture in the Islamic world where architecture and the arts remained closely interlinked with mathematics. Gundissalinus's classification thus helped revive a classical definition of mechanics that contributed to the rising status of the mechanical arts (*scientia de ingeniis*) in the high Middle Ages.[90]

The thirteenth-century French architect Villard de Honnecourt, to whom the earliest surviving Gothic sketchbook is attributed, can be seen as a medieval *mechanicus* whose album includes an assortment of subjects ranging from buildings, carpentry, sculptural details, figural decorations, and machines to geometric drawings. The drawings in the latter category are identified with the caption "All these figures are extracted from geometry." They address problems in architecture, mechanical engineering, and mensuration (e.g., determining from a distance the height of a tower, the width of a river, and the width of a window), some of which find parallels in contemporary European practical geometry manuals. Villard's designs governed by underlying geometric schemes have been compared to the writings of the theologian and philosopher Robert Grosseteste (1175–1253), who regarded the universe as eternally generated by an emanation of cosmic light that behaved according to geometric laws. This was a universe where geometry constituted the basis of all natural phenomena: "It is impossible to know nature without geometry. The principles of geometry have absolute value throughout the universe and for each of its parts. It is by lines, angles, and geometric figures that all natural phenomena must be understood."[91] The anonymous *Constitutions of Masonry,* circa 1400, expressed the Gothic mason's reliance on geometry in similar terms:

> Don't marvel that all science lives only by the science of geometry. . . . There is no tool to work with that has no proportion. And proportion is measure, and the tool



118. Johannes Kepler, selected tiling patterns and geometric solids. From his *Harmonices mundi* (Linz: [n.p.], 1619), book II.

> or the instrument is earth. And geometry is . . . the measure of earth, wherefore I may say that all men live by geometry. . . . You shall understand that among all the crafts of the world . . . masonry has the most notability and the most part of its science is geometry.[92]

The notion of a mathematically ordered harmonic universe, not so different from the cosmologies of medieval Muslim philosophers and theologians discussed in part 3, ultimately went back to Pythagoras and to the cosmological speculations of Plato's *Timaeus.* This notion, which continued to fascinate postmedieval thinkers, was explored in the German astronomer Johannes Kepler's (1571–1630) *Harmonices Mundi,* 1619, a work dealing with the construction of regular polygons and circles as well as regular and semiregular polyhedrons by ruler and compass. In this work Kepler focused on the problem of congruent geometric figures, both planar and spatial, expressed by tilings in contact that left no gaps (fig. 118). The second book of *Harmonices Mundi,* on the congruence of harmonic figures, explained how to fit regular polygons together around a vertex (either to make a pattern that can be extended infinitely to cover a plane [a tessellation] or a closed volumetric figure [a polyhedron]). As we have seen, similar problems had also preoccupied such Muslim mathematician-astronomers as al-Buzjani and the anonymous author of *Aʿmāl wa ashkāl,* which deals with the construction of har-

moniously interlocking similar or congruent geometric figures. Kepler believed that the harmonic properties of regular and congruent geometric figures constituted the root of all order and beauty in the universe:

> Since we have taken it upon ourselves to explain the origin of Harmony and its most powerful effects in the World as a whole, how could we omit to mention the congruence of the figures which are the well-springs of Harmonic proportions? . . . Since the effect these figures have in the realm of Geometry, and in that part of Architectonics which deals with Archetypes, is as an image of and a prelude to their effects beyond Geometry, beyond things conceived in the mind, namely their effects in things natural and celestial?[93]

The geometric design language of Villard reflected a sensibility similar to that of its Islamic counterparts, although the former was dominated by figural imagery (generated by invisible geometric schemata) while the latter foregrounded geometry to an unprecedented degree to compensate for the absence of sculptural programs and narrative cycles. This similarity no doubt was informed by access to comparable practical geometry manuals. Unlike the builders and decorators of Gothic cathedrals, who used simpler geometric formulas, those of Islamic religious monuments gave geometry a much greater visual prominence, complexity, and distinctive appearance, dominated by stars, polygons, calligraphy, and the sculptural forms of the muqarnas. The implied underlying geometry of Gothic decoration was raised to the surface in two- and three-dimensional *girih*s in which unseen geometric grids generated one or more superimposed layers of star-and-polygon patterns. Medieval Islamic vegetal or figural compositions (confined to profane contexts), by contrast, were guided by invisible geometric schemata not so different from those of Villard. The shared preoccupation with geometry often produced similar ways of conceptualizing design problems and similar tastes dominated by geometric or geometrized abstract forms. The ingenious variation of geometric schemes based on the fundamental design concept of "unity in variety" (often assumed to be a visual symbol of the Islamic doctrine of *tawḥīd*) was, therefore, a common denominator of the medieval system of geometric harmonization regardless of religious affiliation.

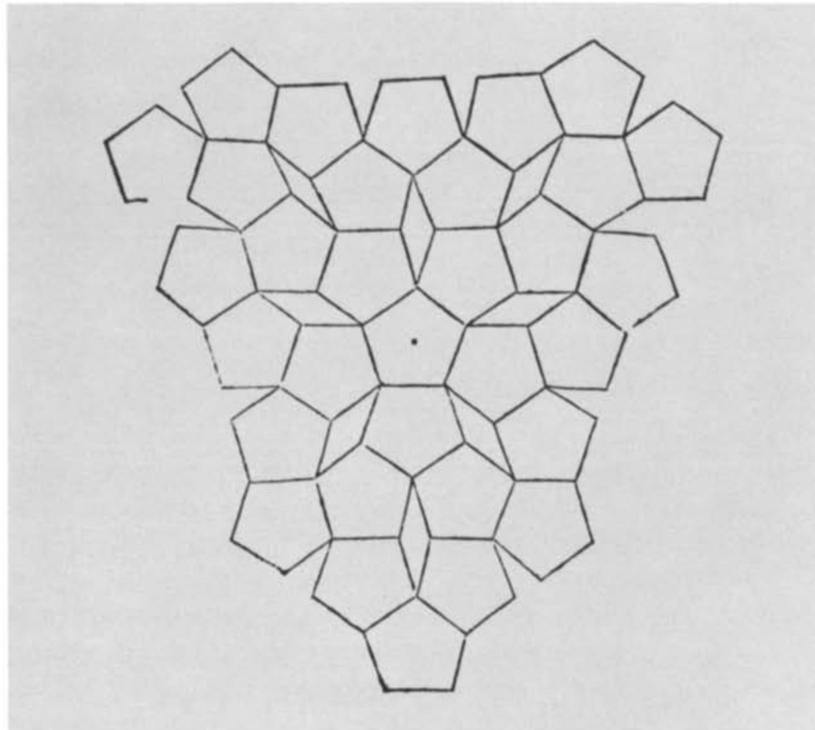
Villard's thirteenth-century sketchbook represented a fully assimilated tradition of practical geometry transmitted by oral workshop traditions and practice-oriented written manuals that began to circulate more widely in Europe in the form of printed booklets after the invention of the printing press, accompanied by the gradual dissolution of the guild system. German manuals of practical geometry, written by such geometer-engineers and master builders as Hans Hoech, 1472, Mathias Roriczer, circa 1486–1490, Erhard Schoen, 1538–1542, and Hans Lautensack, 1563, testify to the continued popularity of geometric constructions in late medieval and early modern Germany.[94]

Even the German painter and engraver Albrecht Dürer (1471–1528) wrote a practical geometry manual entitled *Unterweisung der Messung mit dem Zirkel und Richtscheit in Linien, Ebenen und ganzen Körpern* (Teaching guide to mensuration with the compass and straight edge in lines, planes, and volumes), first published in 1525, with a second edition appearing in 1538. Its geometric constructions, drawn with the aid of basic working tools and without recourse to arithmetic, addressed master masons and artisans in a simple language marked by an absence of theoretical elaboration, much like its predecessors. Dürer's dedication explains that since geometry constitutes the right foundation of all the arts and crafts, he would teach its practical principles: "Therefore I hope that no man of understanding will censure my project and instruction, for it goes forth with good intention for the good of all those desirous of art. Thus it may be useful not only to painters, but also to goldsmiths, sculptors, masons, joiners, and all those who use measure."[95]

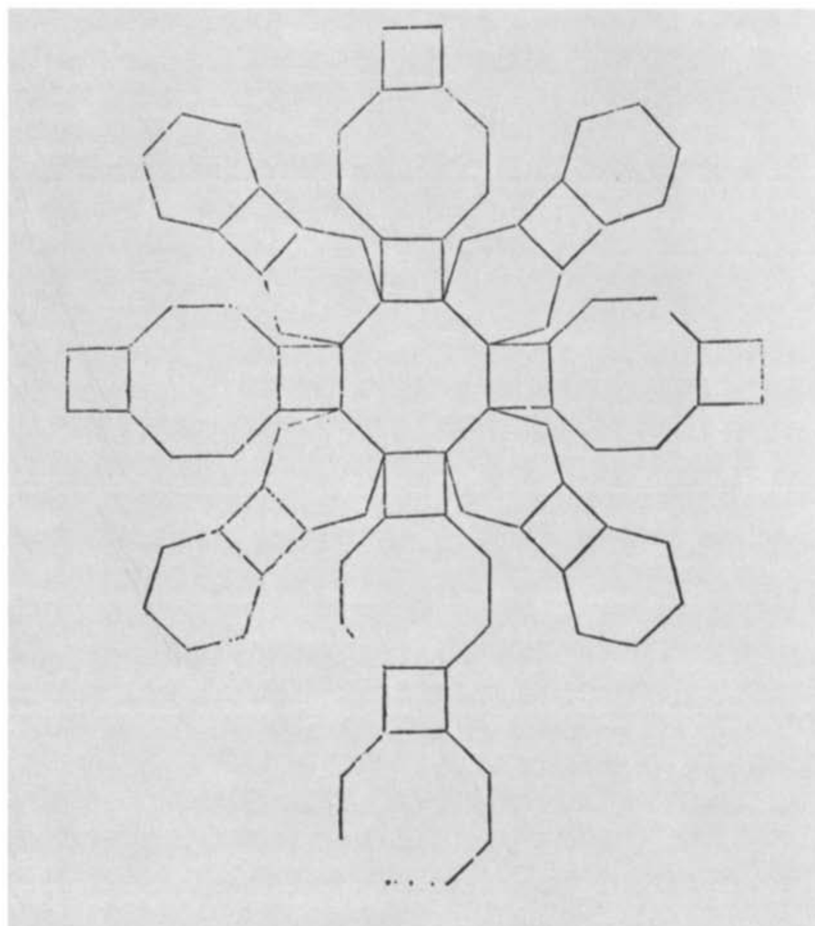
Dürer's *Unterweisung,* which deals with the mensuration of lines, planes, and solids, transmitted to future generations a wide spectrum of geometric constructions that had found a place in both Muslim and Christian craft traditions. These medieval constructions, disseminated by treatises of practical geometry, "how-to" manuals, and workshop drawings, relied on methods of parallel

(orthogonal) projection and transformational geometry based on the rotation of figures. They frequently used approximate rather than scientifically correct constructions of regular polygons, drawn by dividing circles into equal arcs, a process often simplified by the employment of compasses with a single opening.[96] Dürer's *Unterweisung* starts by teaching the geometric constructions of regular planar and spatial figures, including the five Platonic solids and some of the Archimedean semiregular polyhedrons also dealt with in al-Buzjani's practical geometry manual; to these are added some new solids invented by the author. It then discusses conic sections, tiling and tessellation patterns developed from regular polygons in contact, and the development of geometric solids on a plane surface such that they could be cut out of paper to form three-dimensional models (figs. 119, 120). Dürer also addressed the practical applications of geometry to such diverse fields as architecture, engineering, mechanics (e.g., the construction of a sundial), decoration, and typography (showing the derivation of roman letters from the circle, and of the angular Gothic script from squares, trapezoids, and triangles).

Dürer's *Unterweisung* culminates with the novel method of perspective projection developed in Renaissance Italy. Martin Kemp and Jehane R. Kuhn have suggested that the invention of perspective drawing must have been inspired by the practical geometry of mensuration, given its similarity to the routines of indirect measurement from a distance that traditional surveyors



119. Albrecht Dürer, tiling pattern. From his *Unterweisung der Messung mit dem Zirkel und Richtscheit in Linien, Ebenen und ganzen Körpern* (Nuremberg: [n.p.], 1525). Santa Monica, The Getty Center for the History of Art and the Humanities.



120. Albrecht Dürer, paper cutout of a geometric solid. From his *Unterweisung der Messung mit dem Zirkel und Richtscheit in Linien, Ebenen und ganzen Körpern* (Nuremberg: [n.p.], 1525). Santa Monica, The Getty Center for the History of Art and the Humanities.

had used. Kuhn argued that Brunelleschi's method of perspective transcription arose within surveying practice as a topographic technique at a time when the use of measured plans and elevations corresponding to numerical values had become part of Renaissance architectural practice.[97] The camera obscura used by Brunelleschi had already been experimented with during the eleventh-century by Ibn al-Haytham, whose revolutionary *Kitāb al-manāẓir* (Book on optics) described vision in terms of geometric light rays that radiate from visible objects and converge on the pupil of the eye. Translated into Latin as *Perspectiva* or *De aspectibus* in the late twelfth or early thirteenth century, this influential treatise, to which I will return in part 5, was well known in Europe. It had an impact on such thirteenth-century writers as the English philosopher and scientist Roger Bacon, the Polish scientist Witelo, and the English prelate John Peckham and on fourteenth-century writers including the English Scholastic philosopher William of Ockham and the French prelate Nicole d'Oresme. Its fourteenth-century Italian translation was extensively used by the Florentine sculptor Lorenzo Ghiberti (circa 1378–1455), who partially copied its section on visual beauty in his *Commentarii,* and by the artist and scientist Leonardo da Vinci (1452–1519), whose writings on the psychology of vision echo those of Ibn al-Haytham.[98] Nevertheless the implications of this optical treatise and of mensuration manuals for perspective projection would be explored only in Renaissance Europe, a phenomenon that was triggered by a complex set of cultural factors including the change of attitudes toward naturalistic representation.[99]

When Renaissance artists turned away from the transcendental realm of abstraction, the natural world came to be seen as the ultimate source of beauty and proportion. As David Summers noted: "The imitation of appearances might have begun as marginal displays of skill, or as part of a new didactic strategy. . . . Eventually the union of painting and optics in one-point perspective would yield what was understood to be a most perfect universal art, fully adapted to the structure of human vision and perception."[100] In a passage that linked the eye and painting, Leonardo stated, "The eye, that is the window of the soul, is the principal way whence the common sense may most copiously and magnificently consider the infinite works of nature." Summers noted that Leonardo understood the eye not in its previous, medieval sense as an opening through which the soul itself became visible but rather "as an Albertian perspective window, into which light comes and through which the common sense surveys the world."[101] This outward-looking vision was fundamentally different from the inward-looking spiritual vision of medieval artists.

The revolutionary union of painting and optics in Renaissance Italy, adapted to the structure of visual perception, involved positing an observer with a fixed point of view. By contrast, geometric *girih* patterns, composed of interlocking stars and polygons rotating around multiple foci of radial symmetry, embodied a multiplicity of viewpoints contradicting the Renaissance concept of the picture plane as a window frame that cuts through the spectator's cone of vision on which rays converge at a central vanishing point. The absence of a fixed viewpoint in the abstract geometric matrices of *girihs* yielded an infinite isotropic space that amounted to a denial of the naturalistic representation of the visible world. *Girih* patterns filtered the visual data offered by the natural world into mental abstractions. No wonder, then, that these inward-looking abstract images were unconcerned with the spatial coordination of sight and representation through the use of vanishing point perspective. The draftsmen who designed them remained bound to a conception of the picture plane as a window to infinity, filled with symmetrically repeated geometric shapes exhibiting *unendliche Rapport.*

CHAPTER 9. MANUALS OF PRACTICAL GEOMETRY AND THE SCROLL TRADITION

The *Aʿmāl wa ashkāl,* an anonymous treatise on interlocking similar or congruent figures, is the only known "how-to" manual on the drawing methods of two-dimensional *girih* patterns. Appended to an early eleventh-century Persian translation of al-Buzjani's practical geometry addressed to artisans, it provides evidence that later scrolls, which do not have any explanatory texts, grew out of a medieval tradition of practical geometry. The two treatises are bound together with other mathematical and astronomical texts in a manuscript at the Bibliothèque Nationale in Paris, MS Persan 169, that once belonged to an unidentified Ottoman named Sinan Çavuş. Thought to have been copied in the early seventeenth century, this Persian manuscript in the nastaʿliq script originally may have been compiled in the Timurid period, since the latest works it contains were composed in the first half of the fifteenth century. Twenty-five short treatises, either written or translated into Persian, are bound together in this volume, which deserves to be studied in greater detail by historians of science. These treatises deal with arithmetic, astronomy (including two works by Nasir al-Din al-Tusi on the astrolabe and on astrological prognostication), applied mensuration, and practical geometry.[102] The manuscript's consistent focus on praxis, together with its collection of ten works on practical geometry and applied mensuration, suggests that it may have been put together for an architect-engineer (*muhandis*).

The contents of the Paris manuscript support the assessment by historians of science that the Mongol-Ilkhanid and Timurid-Turkmen period, extending between the mid-thirteenth and early sixteenth centuries, was one of consolidation in the field of mathematics rather than one of innovation. In this period important steps taken during the tenth and eleventh centuries were further elaborated by such astronomer-mathematicians as Nasir al-Din al-Tusi who worked with a distinguished team of scientists at the Maragha observatory and its successor in Tabriz. His younger associate and intellectual heir Qutb al-Din al-Shirazi (1236–1311) was an equally prominent scientist whose student Kamal al-Din Abu al-Hasan al-Farisi (d. circa 1320) wrote an extensive commentary on Ibn al-Haytham's early eleventh-century treatise on optics. This significant commentary, which revised the old treatise by adding substantial new sections to it, was typical of the post-Mongol era when earlier scientific works were culturally assimilated through a creative process of reworking and updating.[103] It became common practice to abridge earlier works or to expand them in a revised format with detailed commentaries, a practice indicating that the Islamic world had by that time established its own "classics." Unlike Renaissance Europe, which broke with the immediate past when sources from antiquity were rediscovered, the Islamic East was characterized by a relatively uninterrupted cultural continuity from the early medieval period onward, exemplified by an unbroken chain of transmission of knowledge well into the modern era.

Al-Buzjani's practical geometry manual, on which the mathematician Kamal al-Din Musa b. Yunus b. Manʿa (1156–1242) wrote a commentary in late twelfth- or early thirteenth-century Mosul survives in several Persian translations, one of them included in the Paris manuscript. Accord-

ing to the latter's epilogue, its translation into Persian had been initiated by Abu Nasr Mansur b. ᶜAli Ibn ᶜIraq (fl. 1000), the Khwarezmian astronomer and mathematician who was a student of al-Buzjani. This early eleventh-century abridged translation was copied and revised in two months by the mathematician-astronomer Abu Ishaq b. ᶜAbd Allah Kubanani Yazdi (active in 1442–1443 at Sari and in 1459 at Kirman and Hormuz), who also drew the text's illustrations. The reference to Ibn ᶜIraq suggests that the original translation must have been undertaken in the Khwarezmian capital Gurganj (now Kunya Urgench), which had become a center of learning during the enlightened rule of the Khwarezm-Shahs (995–1017). The brilliant group of figures gathered at that court included Ibn Sina and Ibn ᶜIraq's eminent student al-Biruni (973–1050), who subsequently moved to Ghazna when the Ghaznavid ruler Mahmud (998–1030) conquered Khwarezm. Kubanani Yazdi's copy of this Persian text is evidence of its availability in the Timurid period.[104]

That an Arabic version of al-Buzjani's *Aᶜmāl al-handasa* was also available at the Timurid court is demonstrated by a fifteenth-century copy of it (now at the Süleymaniye Kütüphanesi in Istanbul), transcribed for Ulugh Beg's royal library in Samarqand. S. A. Krasnova, who translated this manuscript into Russian, hypothesized that it must have been brought to Istanbul by Ali Kuşcı, who joined the Ottoman court in 1472 after a brief stay in the Aqqoyunlu court of Tabriz following the death of his royal patron Ulugh Beg.[105]

In addition to al-Buzjani's *Aᶜmāl al-handasa,* the Paris manuscript includes several applied mensuration treatises based on practical geometry. One of these, dedicated to a late twelfth-century *atabeg* of Azerbaijan, deals with measuring the areas of two- and three-dimensional geometric figures and the practical applications of mensuration in land surveying, hydraulic engineering, and architecture. This anonymous text includes such problems as calculating the depth of wells, the height of mountains, the width of rivers, the height of walls in buildings, and the number of bricks required for vaults and domes.[106] Another anonymous mensuration treatise in the same volume includes a similar section on measuring the surfaces of hollow domes (*qubba-i mujawwafa*), vaults, and arches (*āzāj wa ṭīqān*).[107]

The Paris manuscript also contains two undated works on practical geometry and applied mensuration by an otherwise unknown geometer, Abu Bakr al-Khalil al-Tajir (the merchant) al-Rasadi (the astronomer). His *nisba* "al-Rasadi" signals his involvement with astronomy, which is supported in his applied mensuration treatise entitled *Aᶜmāl* (Constructions) where the numerical methods of arithmetic (*uṣūl al-arithmāṭīqī*) used by astronomers are differentiated from the approximative geometric ones used in applied mensuration (*aᶜmāl al-misāḥa be-taqrīb*). This treatise shows how arithmetic operations based on numerical ratios can be translated directly into geometry, exemplified in the work's frequent application of algebra to geometric problems. It deals with the measurement of triangles and the arcs of circles, accompanied by tabulated tables for calculating their most important dimensions. It then turns to measuring volumes and culminates with a section on applied mechanics that discusses pulleys, burning mirrors, and how to determine the height of mountains and the depth of wells, accompanied by technical geometric diagrams.[108]

It is tempting to associate the author of this treatise with the unidentified Abu Bakr whose similar treatise on applied mensuration had been translated in abridged form into Latin as *Liber mensurationum* by Gerard of Cremona.[109] Both works provide tabulated tables for calculating the most important dimensions of geometric figures and apply algebra to the solution of practical geometry problems. Determining the identity of Abu Bakr al-Khalil al-Tajir al-Rasadi becomes particularly important because he is mentioned twice in the *Aᶜmāl wa ashkāl.*[110] His personal contribution to some of the *girih*s included in this undated anonymous treatise is indicated by the remark that master craftsmen (*ustādān*) had questioned him about the different ways in which a particular geometric construction could be drawn; one of his solutions is explained in an accompanying diagram. The same treatise contains another geometric construction by Abu Bakr al-Khalil, which shows how to draw a pentagon inscribed with a five-pointed star by using the chord of an arc as the module. Moreover, the *Aᶜmāl wa ashkāl* includes a tabulated table for the measurements of most commonly used triangles, recalling simi-

lar tables provided in Abu Bakr al-Khalil's *Aᶜmāl,* the applied mensuration treatise bound in the same volume.[111]

The collaboration of this unknown professional mathematician with practitioners recalls the example of al-Buzjani, who held meetings with artisans in tenth-century Baghdad where problems of practical geometry concerning their works were discussed. In addition to Abu Bakr al-Khalil, the anonymous author of *Aᶜmāl wa ashkāl*—who seems to have been a *muhandis* with practical rather than theoretical training in geometry—also provided some solutions of his own to problems raised in these sessions.[112] Perhaps it was al-Buzjani's student Ibn ᶜIraq who introduced such sessions to the court of the Khwarezm-Shahs after he sponsored the Persian translation of his teacher's *Aᶜmāl al-handasa.* If Abu Bakr al-Khalil and the anonymous author of *Aᶜmāl wa ashkāl* were attached to the same court, then this work appended to the Persian translation of al-Buzjani's practical geometry can also be dated to the early eleventh century. Bulatov, who assumed that the anonymous treatise was created as an appendix to al-Buzjani's text, dated both works to the early eleventh-century Khwarezmian court. After developing some of the treatise's repeat units into tiling patterns through symmetrical repetition, he concluded that all of the grid systems used in it already appear on the eleventh- to twelfth-century monuments of Central Asia. An eleventh-century date was also accepted by Golombek and Wilber, who suggested that some of the anonymous treatise's drawings may have been added to the original set during the Timurid period when it was being copied.[113] It is not certain, however, that the *Aᶜmāl wa ashkāl* constitutes an appendix to al-Buzjani's practical geometry. The fact that it follows al-Buzjani's related work in the Paris manuscript, which is a collection of many treatises, may have been a coincidence. Therefore, its date and provenance remain uncertain. Its only surviving copy exhibits linguistic archaisms also found in the accompanying al-Buzjani text that Edgar Blochet identified as a pre-thirteenth-century work.[114] On the basis of a pentagonal seal seen both in the anonymous treatise and on the decorations of the so-called Abbasid Palace in Baghdad, Chorbachi and Arthur L. Loeb suggested that the treatise may have been compiled before that palace's construction between 1180 and 1230.[115]

The date of *Aᶜmāl wa ashkāl,* in which the names of Ibn al-Haytham and Abu Bakr al-Khalil are mentioned, can be determined with more certainty once the latter's identity is ascertained. If he was indeed the author of *Liber mensurationum,* which Gerard of Cremona had translated sometime in the twelfth century, then an eleventh-century date may not be unlikely for the *Aᶜmāl wa ashkāl.* This anonymous treatise appears to have been revised while it was being copied in the Timurid period, most likely by the same Kubanani Yazdi who prepared the text and drawings of al-Buzjani's practical geometry. Nevertheless it seems that we primarily are dealing with an early medieval corpus of geometric constructions compiled sometime between the early eleventh and early thirteenth centuries.

Although a detailed analysis of the *Aᶜmāl wa ashkāl* lies beyond the scope of this book, its relationship to later *girih* scrolls preserved from the Timurid period onward needs to be assessed. This twenty-page "how-to" manual, providing instructions for the construction of sixty-one repeat units for planar geometric patterns, is of particular interest because it shows how the general principles outlined in the practical geometries of al-Buzjani and others were used in developing interlocking star-and-polygon compositions (see figs. 108–114).

The *Aᶜmāl wa ashkāl* often provides very complicated, scientifically correct geometric constructions that are accompanied by simpler methods for constructing the same patterns. In one example a *girih* pattern requiring the use of an angle-bracket ruler, which facilitated sketching conic sections, is accompanied by two simpler solutions of the same problem arrived at by the method of approximation.[116] One of these solutions reflected the current working methods of some artisans (*baᶜżi az ṣunnāᶜ*) who drew the repeat unit of this *girih* not according to the geometrically correct way (*ṭarīq-i handasa*) but in an easier method that approximated it very closely (*ᶜaẓm nazdīk ast*). This involved dividing the length and width of the rectangular repeat unit into seven and six equal modular parts, respectively, a construction corresponding to the numerical ratio 7:6.[117] The anonymous author offered a

second approximate method for the same pattern that he worked out himself, a method that dominates the Topkapı and Tashkent scrolls. This involved dividing the right angle at the lower right corner of the rectangular *girih* into nine equal parts (angle modules) by drawing a quarter circle subdivided by eight equidistant radii, four and five parts of which closely approximated (*ghāyat taqrīb*) the required angles.[118]

These examples demonstrate that lines and angles could be expressed in terms of modular units corresponding to numerical ratios in the geometric language of *girih*s. Such modular units of measurement translated algebraic equations into the visible geometric relationships of *girih*s, created by the harmonic division of square and rectangular repeat units into interlocking similar or congruent figures obeying the laws of symmetry. The use of ratios was an important element in practical geometries whose indirect measuring techniques relied on proportion, that is, on finding the ratio of an unknown quantity to a known one. That the *girih*s of the anonymous treatise were based on specific ratios is reflected in its instructions that explain how to draw the ratio or proportion (*nisbat*) of a given geometric construction (*ʿaqd*).

The method of dividing an arc into equal modules by equidistant radii to approximate the angles required in constructing star-and-polygon patterns is shown as one of many in the *Aʿmāl wa ashkāl.* Eventually, however, this practical method came to dominate the simpler geometric language of Timurid-Turkmen and Uzbek scrolls. The method is based on an axiom explained at the beginning of the treatise: When any triangle is inscribed in a circle, the ratio of its angles is equal to that of the arcs cut off by those angles. This meant that the angles of triangles or polygons inscribed in circles could be expressed in terms of modular arc units. So, for example, to construct a triangle with angles equal to three, four, and five modules, one simply had to sketch a circle, divide its circumference into twelve parts, and then with chords join three, four, and five parts. The anonymous treatise uses such angle modules instead of the degrees, seconds, and minutes employed by astronomers and arithmeticians in measuring angles. Besides compasses and the angle-bracket ruler for sketching conic sections (see figs. 107, 108), it also mentions special set squares (*gūnyā*), corresponding to the most commonly used right angles, that facilitated the tedious process of dividing arcs into equal parts. These included set squares corresponding to five-angle modules (i.e., 30-60-90 degrees) and six-angle modules (i.e., 36-45-90 degrees, used in *girih*s with pentagons and decagons).[119]

If it was indeed composed in the early eleventh century, the *Aʿmāl wa ashkāl* brings us close to the moment when the *girih* mode was being formulated by artisans under the direct supervision of professional mathematicians. The text's references to newly discovered methods for constructing particular geometric patterns and to experiments with several alternative techniques for drawing a given pattern capture the inventiveness of the setting in which it was composed. Its wide variety of geometric constructions, unlike the relatively standardized repertory of later scrolls, suggests that it must have been created at a time of rigorous experimentation. This was a milieu in which mathematicians collaborated with practitioners, helping them find suitable approximations of scientifically correct geometric constructions that could simplify application to various fields. That process often involved the translation of numerical ratios into the proportional relationships of geometric forms, a translation facilitated by the common habit among mathematicians of providing geometric proofs for algebraic problems. The *Aʿmāl wa ashkāl,* therefore, includes *girih*s that are geometric expressions of algebraic problems, some of them involving complex cubic equations with solutions based on intersecting conic sections.[120] The haphazard organization of the treatise suggests that its anonymous author, who was personally involved in adapting scientifically accurate solutions into simplified approximations more suitable to artisanal working methods, compiled it as a spontaneous record of ongoing experiments.

The use of several constructions from al-Buzjani's practical geometry in the anonymous treatise shows the link between these two application-oriented manuals. One of those constructions is a square containing a smaller rotated square at its center (whose four sides are extended until they touch the larger framing square, creating four kite-shaped paraboloids or four conic triangles along each side). This

algebraically definable geometric scheme, which became widely used in the Timurid period as a proportioning device in the setting out of ground plans and decorative panels, is encountered not only in the anonymous treatise (see figs. 108, 112) but also in the Topkapı scroll (see cat. nos. 59, 61, 72c) and in the much later Mirza Akbar scrolls (see fig. 34). Known today among contemporary Iranian builders as *chahār langeh* (lit., "four legs," referring to the extended sides of the central square) or as *chahār turunj* (lit., "four kite-shaped paraboloids, or conic quadrilaterals," referring to the shapes abutting the central square), its use has also been documented in Indian mathematical treatises.[121]

The practical ability to employ such geometric schemata in the design process did not imply an ability to understand them algebraically in terms of numerical equations. Initially formulated with the help of mathematicians, such geometric schemes eventually became codified in scrolls reflecting workshop practices inherited over the generations. Al-Buzjani's late tenth-century manual on practical geometry, the anonymous treatise put together sometime between the early eleventh and early thirteenth centuries, and the Topkapı scroll compiled in the late Timurid-Turkmen period can therefore be seen as three successive stages in the evolution of a geometric design tradition. A comparison of these three documents demonstrates a striking continuity in drafting methods, testifying to the lasting impact of late tenth- and early eleventh-century developments in practical geometry on future generations of architects and decorators. The *girih*s of the anonymous treatise, annotated with "how-to" instructions that do not explain every step, addressed designers already acquainted with the basic methods of constructive geometry explained in al-Buzjani's attached manual (such as dropping perpendiculars or drawing polygons by dividing circles). The Topkapı scroll further distilled, revised, and codified the early medieval *girih*s of the anonymous treatise, which constituted a culmination of the geometric constructions contained in al-Buzjani's practical geometry.

The Topkapı scroll was the end product of a long process of elaboration of early medieval *girih*s by successive generations of master builders who visually transmitted them to future generations by means of a sophisticated system of graphic notation. The omission of a text with "how-to" instructions in this scroll shows that by the late Timurid-Turkmen period *girih*s were so well understood and assimilated into oral craft traditions that one only required drawings serving as mnemonic devices to record codified workshop practices. Some of the more complicated geometric methods described in the anonymous treatise were replaced in the scroll by the simpler methods of approximation, a development perfectly summarized by Jones:

> As with proportion, we think that those proportions will be the most beautiful which it will be most difficult for the eye to detect; so we think that those compositions of curves will be most agreeable, where the mechanical process of describing them shall be least apparent; and we shall find it to be universally the case, that in the best periods of art all mouldings and ornaments were founded on curves of a higher order, such as the conic sections; whilst, when art declined, circles and compass-work were much more dominant.[122]

Although the Topkapı scroll by no means represents a "decline," its *girih*s generated by approximative methods no longer exhibit the same complexity as their counterparts in the *Aʿmāl wa ashkāl,* seemingly created in a period of immense creativity in the field of geometry. Comparing the *girih*s of these two documents reveals that the former rely more heavily on circles and compass work, whereas the latter are based on alternative methods ranging from simple constructions to complex ones using conic sections. Such a comparison seems to support the early date of the anonymous treatise, whose *girih*s are generally consistent with the types of geometric patterning seen on the brick buildings of the eastern Islamic world between the eleventh and early thirteenth centuries. Its variegated grid systems would eventually be subordinated to the dictatorship of radial grids subdivided by equidistant radii that became particularly dominant in the late Timurid-Turkmen period. Comparing the *Aʿmāl wa ashkāl*

with the Topkapı and Tashkent scrolls confirms this important transformation and supports the view that the highly standardized geometric patterns of post-thirteenth-century monuments in the Islamic East no longer exhibited the same complexity and variety as those encountered in earlier structures built between the late tenth and early thirteenth centuries, when advances in the mathematical sciences were still at their peak.

Although several compositions in the *Aᶜmāl wa ashkāl* find direct parallels in the Topkapı scroll, many of them have been eliminated altogether. For example, the treatise's complex triangulation methods, rotations of triangles within triangles, harmonic divisions of polygons into congruent parts, and transformations of similar polygons into one another do not find their counterpart in the Topkapı scroll, which is dominated by composite radial grid systems producing a wide variety of star-and-polygon patterns in two and three dimensions. Nevertheless, schemes based on rotating a square within another square and radial grids organized around dynamic axes of symmetry (oblique cross axes or diagonal lines cutting repeat units into congruent parts) are common in both documents, which contain some similar *girih*s. (Compare, for example, fig. 109 with cat. no. 73; fig. 111 with cat. no. 34; fig. 112 with cat. no. 61; and fig. 113 with cat. no. 70.) These comparable *girih*s were generated by similar uninked grid lines scratched on the paper (see figs. 109b, 113b), sometimes indicated on the final pattern as solid or dotted construction lines in red or black ink. The presence of several unfinished irregular patterns in the anonymous treatise (see figs. 109a, 110) once again captures the experimental nature of this document, which seems to have been compiled at a time when *girih*s were being invented through trial and error methods, unlike the more fully worked out patterns codified in later scrolls.[123] Comparing the two documents also shows that some of the *girih*s in the anonymous treatise were further fragmented into smaller geometric compartments in the Topkapı scroll (e.g., see fig. 111 and cat. no. 34).

Despite their striking parallels the Topkapı scroll and *Aᶜmāl wa ashkāl* embody different design repertories consistent with their respective times of compilation. The latter document, for example, does not include any radial arch-net or muqarnas vault projections, so characteristic of the Topkapı and Tashkent scrolls. Nor does it have geometric and calligraphic patterns intended for *bannā'ī* brick masonry. Its inventive schemes eventually culminated in the intricate *girih*s of Timurid-Turkmen and Uzbek scrolls that explore all the possible permutations of inherited patterns. Despite their visual complexity, however, the later scrolls were based largely on standard formulas. They represented a distillation of practical geometry, ingeniously adapted to the working methods of master builders and decorators. It is unlikely that these scrolls, exhibiting a sophisticated capacity to manipulate geometric grids to create complex constellations of pattern, were informed by a deep theoretical knowledge of mathematics.

The Topkapı scroll, then, is a corpus of schemata accumulated over the centuries that reflects the collective memory of master builders who endlessly refined early medieval *girih*s but still possessed a creative geometric imagination, nourished by manuals of practical geometry, workshop drawings, and by empirical experience acquired during apprenticeship. Its visual complexities are reminiscent of the Alhambra's intricate geometric revetments, which also represent the culmination of earlier experiments at a time when mathematical creativity had lost its initial vigor. The celebrated geometric fantasies of the Alhambra were based on brilliant elaborations of by-then-redundant formulas, most likely transmitted through now-lost scrolls (whose memory may have been preserved in López de Arenas's *Breve compendio de la carpintería de lo blanco y tratado de alarifes*).

The *Aᶜmāl wa ashkāl* dealt with the proportional division of the plane (considered limitless on all sides) into similar or congruent geometric shapes (known by mathematicians as tilings or tessellations) that cover surfaces without leaving any gaps or empty spaces. The cutting of the plane into a jigsaw puzzle of proportionally related pieces symmetrically multiplied by the operations of translation, rotation, reflection, and glide reflection recently has been analyzed by crystallographers and explored in the work of the twentieth-century Dutch graphic artist M. C. Escher (whose fascination with tilings that fill the plane and space without any gaps were inspired primarily by the Alhambra).[124] Although the *Aᶜmāl wa ashkāl* does

not include muqarnas projections, a few of its *girih*s composed of squares and rhombuses do recall orthogonal muqarnas vaults such as the one represented on the thirteenth-century Takht-i Sulayman tablet (see figs. 1, 114). These two-dimensional patterns suggest that the muqarnas must have evolved from a similar kind of geometry, involving the proportional division of space into closely packed compartments without leaving any gaps. The simplest examples of muqarnas formations are in fact nothing but stereometric exercises in the cubic division of space; the shapes enveloping their carved cells often are full cubes in contact.[125]

The regular division of space into similar and congruent three-dimensional cells, or space tilings, was a natural extension of experiments with plane tilings. Just as the simplest orthogonal muqarnas compositions exhibit an affinity to two-dimensional surface patterns generated by rectilinear grids (see figs. 1, 46–50, 52), the far more complex radial muqarnas projections of the Topkapı and Tashkent scrolls can be read as spatial interpretations of two-dimensional patterns with interlocking stars and polygons. Extending the idea of filling a plane with congruent stars and polygons into three dimensions must have been a natural outcome of exercises in practical geometry and mensuration manuals, which proceed from constructions in the plane to constructions in space. Just as "knotted" grid lines divided surfaces proportionally, so too could intersecting planes be arranged to divide space into repetitive cells arranged in corbeled tiers. This affinity explains why muqarnas projections (three-dimensional space-filling patterns) are always juxtaposed with geometric interlaces (two-dimensional surface-filling patterns) in Islamic scrolls that brought experiments initiated by early medieval designers to their logical conclusion with collections of congruent tilings, both planar and spatial.

The elusive muqarnas can therefore be defined as a geometric formation with corbeled tiers of space-filling lattices that homogeneously partition space into similar or congruent cells connected by filler elements. Such a definition is consistent with al-Kashi's description of the muqarnas in 1427 as a vaulted roof resembling a gradine or staircase (*madraj*), with the facets of each adjacent cell (*bayt*) joining one another at different angles along successively corbeled tiers (*ṭabaqa*) parallel to the horizon. The measure of the base of the largest facet constituted the module (*miqyās*) of the muqarnas, which generated commensurable shapes joined together in perfect harmony (see "The Muqarnas" in the present volume).[126] The muqarnas, then, was the product of the same type of geometric experimentation that culminated in the invention of planar *girih*s, which embodied classical aesthetic notions of proportionality rather than the so-called horror vacui of the Islamic psyche. It did not appear all of a sudden in different places through a mysterious process of simultaneous combustion reflecting a specifically Muslim weltanschauung but was most likely disseminated by itinerant workshops, design manuals, and drawings from Baghdad or other courts that emulated its artistic, scientific, and intellectual innovations.[127]

Two- and three-dimensional geometric patterns, often juxtaposed on buildings, furniture, and objects, constituted complementary aspects of a single mode of design that was expressed through proportionally related planar and spatial networks. The aesthetic reaction such patterns could evoke is captured by Ibn Jubayr's description from the 1180s of the ivory-and-ebony-inlaid joined-woodwork minbar in the Great Mosque of Aleppo, in front of which "the eyes enjoy one of the most beautiful sights in the world." He identified this minbar, composed of interlocking stars and polygons joined "without apparent division" and topped by muqarnas tiers, as an exquisite example of *qarbaṣa* work, a term that complicates the controversial etymology of *muqarnas* (spelled variously as *muqarbaṣ* or *muqarbas* [the source of the Spanish term *mocarabe*], and as *muqarnaṣ* or *muqarnas*).[128] Ibn Jubayr's description suggests that intricately joined two-dimensional star-and-polygon patterns may originally have been considered an integral part of *qarbaṣa* or *qarnaṣa* work, before *muqarnas* became a more specialized term referring to "stalactites."

Ibn Jubayr was not the only person to derive aesthetic pleasure from harmoniously combined two- and three-dimensional *girih*s. The anonymous author of the *Aʿmāl wa ashkāl* similarly praised one of the *girih*s contained in that work as "extremely elegant" (*be-ghāyat laṭīf ast*). Like the

treatise itself, based on an unarticulated theory of beauty relying on a harmony of interrelated parts, this remark echoes the fascination with the aesthetics of proportion in medieval Islamic texts to which I will turn in part 5.[129] Ibn Khaldun also regarded geometric woodwork as "very elegant," just as López de Arenas described the wooden muqarnas as possessing a "harmony that appears very gracious to the sight."[130]

These aesthetic reactions imply that the link between the mathematical sciences and modes of geometric design transcended merely technical goals. The abstract language of geometry, through which *ars* could be raised to the level of *scientia*, left a profound impact not only on design methods but also on medieval aesthetic sensibilities. The *girih* mode thrived on the arithmetic irrationality of geometric proportions that were instinctively pleasant to the eye but remained a puzzle to the inquiring mind. This is eloquently expressed in Dost Muhammad's preface to the Bahram Mirza album of 1544 where the *band-i rūmī* patterns drawn by a Safavid graphic artist (*ṭarrāḥ*, lit., "line-artist") are described as being "unfathomable to even the most discerning eye." Visually pleasing, yet undecipherable geometric patterns often evoked a sense of astonishment and wonder with their ingeniously contrived and startling effects (*ʿajīb*) that were so prized by patrons of art and architecture. This is captured in al-Jazari's description of the metalwork door with interlocking geometric units included in his book on ingenious mechanical devices: "It is the chef-d'oeuvre, to view it saddles are strapped on [i.e., to control one from shaking]. Truly it is the pearl, the orphan, a priceless possession" (see figs. 115–117).[131] This passage reflects al-Jazari's enormous pride in his own ingenuity, implied in the term *ḥiyal* that underlines the intellectual status of geometric artifices invented by the cunning intelligence of their creators. Evliya Çelebi described the multilayered *girih*s of gates, minbars, and mihrabs in similar terms, praising the ingenious talent (*maʿrifet*) of their designers, which at times approached miraculous saintly powers (*kerāmet*) or licit magic (*siḥr-i mübīn*). Even the scrutinizing gaze (*imʿān-i naẓar*) was not equipped to figure out these wonderful (*ʿibretnümā, ʿibretnümūn, ʿacā'ib, ġarā'ib*) compositions that invariably induced a sense of admiration and astonishment.[132]

Caʿfer, the seventeenth-century author of the *Risāle-i Miʿmāriyye*, provided a fascinating description of the bewildering effects produced by the ingeniously interlocked figures of a wooden reading lectern featuring "geometric forms with sides joined to one another" that the architect Mehmed had presented to the Ottoman sultan Murad III (r. 1574–1595):

> When it was placed in the Exalted Presence, that worldly-wise and blessed sultan, scrutinizing and examining it with care, saw that the Holy Kur'ān had no such peerless throne and that its equal was not to be found in the world. From top to bottom [it was covered with] the interlocking sides of triangles and quadrangles and the sides of pentagons and hexagons and heptagons, and the patterns were possessed of various forms. That is, looking from one angle, one type of form of circle was seen, and when one looked again at that place from another angle, other types of designs and patterns emerging, other forms appeared. However much the point of view was changed, that many forms were transformed into other shapes. When the late [sultan], out of his delight, turned and examined and inspected it, now from this direction, now from that, he recited extemporaneously this noble verse. "God! God! What are these beautiful forms? Like wine, they instantly caused me to lose my head."[133]

This rare description once again highlights the aesthetic value attached to intricately fitted star-and-polygon patterns that could evoke an intoxicating sense of delight mixed with wonder and at the same time testify to the inventive skill of the designer who had created them as abstract figments of the imagination. The reference to intoxicating delight recalls the overtones of the notion of taste (*dhawq*, the power of aesthetic appreciation) in mystical usage where it denotes a kind of ecstatic enjoyment and intoxication that has a noetic quality.[134]

Nervously pulsating around multiple foci of

rotational symmetry, labyrinthine *girih* patterns acted as seductive magnets that afforded no rest to the attentive gaze. Seeing became, in effect, reinventing new patterns each time the gaze attempted in vain to fix itself on these interpenetrating geometric shapes or to dissect their concealed underlying schemes. With their restless flux of geometric figures that continually metamorphosed into one another from whatever direction one looked, star-and-polygon patterns seemed to deny the static viewpoint of a fixed spectator with a limited span of focused vision. To use Norman Bryson's distinction between the "Gaze" and the "Glance," such patterns were diametrically opposed to the prolonged gaze encouraged by monocular perspective. Instead they required the "flickering, ungovernable mobility of the Glance" in which the apprehension of the compositional order was perpetually postponed to evoke a sense of wonder and awe, the prelude to contemplative wisdom.[135]

Like Caᶜfer, Viollet-le-Duc described the aesthetic effect produced by geometric *entrelacs* as one of vertigo: "One is seized by vertigo with these interpenetrating networks of straight and bent lines that form a concrete and harmonious ensemble, but whose combinations seem to slip away from examination." Geometric patterns with dazzling displays of linear interlacement that defied quick apprehension induced a form of visual intoxication, a disorienting dizziness of unsettled vision lost in wonderment. A similar yet much more intense aesthetic effect could be triggered by the wonders of divine creation, as the Koranic passage quoted on the *artesonado* woodwork ceiling at the Alhambra's Hall of Ambassadors implies: "Thou seest not in the creation of the All-Merciful any imperfection. Return thy gaze; seest thou any fissure? Then return thy gaze again, and again, and thy gaze comes back to thee dazzled, aweary" (67: 3–4). The geometric sophistications of *girih*s that intentionally dazzled the eye to the point of blindness were not only informed by mathematical concepts but also by aesthetic theories of sublime beauty and the psychology of visual perception. Their bewildering vertiginous effects that inscribed subjectivity into the optical field could produce a wide range of contextual associations and aesthetic reactions.[136]

NOTES TO PART 4

1. For this quotation and an analysis of its meaning in the context of the construction of Milan cathedral, see Ackermann 1949.

2. Ibn al-Nadīm 1970, 2: 634ff. For the impact of the mathematical sciences on Gothic design methods, see Harvey 1971, 36, 41; and Bucher 1972, 532. A bibliography on medieval architectural mathematics and mechanical sciences is provided in Crombie 1959; and Clagett 1959.

3. The transmission of Greek learning is discussed in Nasr 1976, 9–12; Mieli 1938; O'Leary 1979; Goldstein 1964, 132–33; Fakhry 1983, 1–36; and Kraemer 1986, 84–86. For the Sabaeans, see Marquet 1966–1967. According to the Arab historian and encyclopedist al-Nuwayri (1279–1332), the Sabaeans were famed for their artists: "Specialties in the sciences and praxis: The scholars of Greece, the physicians of Jundishapur, the artists of Harran, the storytellers of Yemen, and the scribes of the Sawad"; cited in Wiedemann 1970, 867. The twelve shrines of the Sabaeans on the sacred enclosure at Harran are referred to in Ibn al-Nadīm 1970, 2: 745–73. See idem, 755 n. 50, where these shrines are described as: "(1) shrine of the Primal Cause, a hemisphere; (2) of Intelligence (al-ᶜAql), a circle; (3) of the Soul (al-Nafs), a circle; (4) of Form (al-Ṣūrah), perhaps meaning 'Space,' no shape cited; (5) either Sequence (Time), called al-Silsilah by al-Masᶜūdī, or the Governing, called al-Sīyāsah in al-Maqrīzī and al-Dimashqī, circular; (6) (al-Zuḥal) (Saturn), hexagonal; (7) al-Mushtarī (Jupiter), triangular; (8) al-Mirrīkh (Mars), square; (9) al-Shams (the Sun), square; (10) al-Zuharah (Venus), elongated triangle; (11) ᶜUṭārid (Mercury), square outside but hexagonal inside; (12) al-Qumar (the Moon), five-sided. Each shrine had an idol, also a special metal and color" corresponding to the planets. For a description of these shrines constructed in allegorical geometric shapes and materials, which were associated with the Sabaean mysteries, see also al-Masᶜūdī 1865, 4: 61–62.

4. Souissi 1982. See idem, 414: "An important area in the application of geometry is that of architecture and sculpture; Muslim art, inspired by geometry, invented the extended [*sic*, pointed?] arch, cupolas resting on regular polygons, corbellings, stalactites, groups of polyhedrons of stucco and light. The work of the sculptor in stone or in stucco was designed by the mathematicians."

5. The reference to Masᶜud I is from Bayhaqi's *Tā'rīkh-i Masᶜūdī* (History of Masᶜud), cited in Wilber 1976, 31; for the treatise written by the king of Saragossa, see Hogendijk 1986.

6. al-Fārābī 1949a. See also the translation of al-Farabi's classification of sciences into German in Wiedemann 1970, 328–47. Islamic classifications of the sciences are discussed in Gardet and Anawati 1948, 101–24; and Bosworth 1963.

7. Ikhwān al-Ṣafā' 1928, 1: 42. The mathematical sciences are dealt with in epistles 1–10, pp. 23–362.

8. Translated in Rosenthal 1975, 65.

9. For al-Buzjani's treatise on practical geometry, see part 3, n. 87, above. Al-Farabi's geometry treatise, which al-Buzjani is believed to have taken as a model, is translated into Russian in al-Fārābī 1972, 91–231. For this treatise, *Kitāb al-ḥiyal al-rūḥāniya wa al-asrār al-ṭabīᶜīya fī daqā'iq al-ashkāl al-handasīya* (Book of pneumatics and natural mysteries about the subtleties of geometric figures), the sole manuscript of which is in the Uppsala University Library, MS Tornberg 324, see Kubesov and Rosenfeld 1969. The attribution of this manuscript to al-Farabi is disputed in Hogendijk 1985, 62. Another geometry treatise of al-Farabi exists in Oxford, *Kitāb buġyat al-āmāl fī ṣināᶜat al-raml wa taqwīm al-ashkāl* (Book on necessary operations in the science of divination and the construction of shapes), MS Marsh 216 (Uri. 1, 956), Bodleian Library. Bulatov pointed out that the Oxford manuscript is not related to divination (*al-raml*) as its misleading title suggests but to geometric constructions; see Bulatov 1988, 89. For these al-Farabi manuscripts and further bibliography, see Sezgin 1974, 295–96.

10. For the geometric shapes of the Sabaean temples, see part 4, n. 3, above.

11. Proclus 1970. Al-Kindi's work is cited in Ibn al-Nadīm 1970, 2: 619. For the Brethren's correlation of the five elements with the Platonic solids, see Ikhwān al-Ṣafā' 1975, 119, 547–48.

12. This lost work by al-Buzjani is cited in Ibn al-Nadīm 1970, 2: 668; see also Sezgin 1974, 325. In contemporary astronomical treatises circular diagrams played a central role.

13. The known Arabic manuscripts of al-Buzjani's practical geometry are MS Ayasofya 2753, Süleymaniye Kütüphanesi, Istanbul; and MS 68, Biblioteca Ambrosiana, Milan. The first one is translated into Russian in Krasnova 1966, 56–140. For these manuscripts and related bibliography, see Sezgin 1974, 321–25. Another Arabic copy in the Dar al-Kutub, Cairo, is mentioned in Chorbachi 1989, 769. For the early eleventh-century Persian translation of this text in MS Persan 169, sec. 23, fols. 141v–179v, Bibliothèque Nationale, Paris, see Woepcke 1855; and for an adaptation of this text into modern Persian, see al-Būzjānī 1990–1991. A late tenth- or early eleventh-century Persian translation prepared for the Buyid ruler of Iran, Abu Mansur Baha' al-Dawla (r. 998–1013), is in MS 37, Imām Rižā, Mashhad. Another eleventh- or twelfth-century Persian translation is in MS 2876, fol. 36ff., Kitabkhane-i Merkez-i Danishgah, Tehran. The copy of an Arabic commentary written in Mosul on al-Buzjani's practical geometry by Kamal al-Din Musa b. Yunus b. Manᶜa, known as Ibn Manᶜa (1156–1242), is in MS 5357, sec. 139, fol. 6ff., Imām Rižā, Mashhad. Al-Buzjani's emphasis on praxis may have been inspired by the type of mathematical education he received from his paternal uncle who had studied geometry under Abu al-ᶜAla' b. Karnib, renowned as a master in the "arts of teaching and geometry," according to Ibn al-Nadīm 1970, 2: 649, 667. Al-Buzjani's popularizing works included an abbreviated version of Ptolemy's *Almagest*, simplified for nonspecialists interested in astronomy. In it he separated geometric from arithmetic demonstrations so that geometer-engineers (*muhandis*) and calculators (*ḥāsib*) trained in only one of these branches could benefit from it; those acquainted with both methods could join the two types of demonstration on their own. The text showed the calculation of the chords of a circle without the aid of numerical formulas, just by using simple geometric shapes (e.g., the sides of the equilateral triangle, square, pentagon, hexagon, octagon, and dodecagon) and included tables of trigonometry that made readily available the new developments in that field; see Carra de Vaux 1892. Al-Buzjani also wrote a practical manual on applied arithmetic that addressed the needs of scribes and secretaries; see al-Būzjānī 1971; and Saidan 1974.

14. For the anonymous treatise, see MS Persan 169, sec. 24, fols. 180r–199v, Bibliothèque Nationale, Paris. It is described in Blochet 1905–1934, 2: no. 772, 41–47; and Richard 1989, 187, where its title has been misread as *Fī madākhil al-ashkāl al-mutashābiha aw al-mutawāfiqa* (Introduction to similar or congruent figures). The correct reading has been provided in Chorbachi 1989, 764, and in al-Būzjānī 1990–1991, where *madākhil* (introduction) has been read as *tadākhul* (interlocking), a reading that is more appropriate in terms of the treatise's contents dealing with interlocking geometric figures. For references to the practical geometry of al-Buzjani and the anonymous treatise, see Woepcke 1855; Prisse d'Avennes 1983; Bulatov 1988; Golombek and Wilber 1988; Holod 1986; idem 1988; Chorbachi 1989; and Chorbachi and Loeb 1992. Chorbachi's doctoral dissertation on the anonymous treatise, "Beyond the Symmetries of Islamic Geometric Patterns: The Science of Practical Geometry and the Process of Islamic Design," completed at Harvard University in 1989, is not available for public use. I regret not having had access to this important study that awaits publication. An abbreviated Russian translation of the anonymous treatise was published as an appendix in Bulatov 1978, a book that appeared in a revised edition; see Bulatov 1988, 315–40. For a recent Iranian publication of al-Buzjani's practical geometry and the anonymous treatise, see al-Būzjānī 1990–1991. The various dates proposed for the anonymous treatise are discussed in part 4, pp. 167–75; see nn. 113–15, below.

15. Kubesov and Rosenfeld noted that the treatise of al-Farabi finished on 7 July 933 contains a foreword and ten books (*maqālāt*), all of which are included in al-Buzjani's differently organized treatise.

16. For al-Buzjani's geometric constructions, see Krasnova 1966, 56–140. Burning mirrors are concave mirrors that, by concentrating the reflected rays of the sun at a focus, cause them to set fire to objects.

17. See Woepcke 1855; Suter 1922; and idem 1986, 2: 635–51.

18. Also dealt with by ancient Greek mathematicians, similar geometric constructions had been treated in the early ninth-century geometric works of al-Kindi whose lost treatises listed by Ibn al-Nadim included *Risāla fī taqrīb qaul Arshimīdis fī qadr quṭr al-dā'ira min muḥīṭihā* (Approximating Archimedes's statement about the measuring of the diameter of a circle from its circumference), *Risāla fī taqrīb watar al-dā'ira* (Approximating the chord of a circle), *Risāla fī taqrīb watar al-tisᶜ* (Approximating the chord of a ninth [i.e., the line marking a segment equal to a ninth of a circumference]), *Risāla taqsīm al-muthallath wa al-murabbaᶜ wa ᶜamalihimā* (Dividing the triangle and the square and their constructions), and *Risāla fī qismat al-dā'ira thalāthat aqsām* (Dividing the circle into three parts). These titles suggest that al-Kindi dealt with approximations of complex geometric constructions and with methods of proportioning; see Ibn al-Nadīm 1970, 2: 619; and Sezgin 1974, 255–59. Krasnova listed among the earliest examples of Arabic works on constructive geometry dealing with approximate solutions a treatise by Thabit b. Qurra, who had translated Archimedes's related work entitled *ᶜAmal al-dā'ira al-maqsūma bi-sabᶜat aqsām mutasāwiya li-Arshimīdis* (On dividing the circle into seven equal parts by Archimedes). This treatise deals with twelve geometric constructions addressing such problems as dividing an angle into three equal parts, dividing lines into proportional segments, dividing a triangle into proportional parts, triangulation, inscribing broken lines in the arc of a circle in proportional relations, and dividing the circumference of a circle into proportional parts. For a discussion of geometric works related to that of al-Buzjani, see Krasnova 1966.

19. The two treatises of Apollonius on cutting lines and surfaces in ratio, whose Greek originals are lost, are cited in Ibn al-Nadīm 1970, 2: 637–38, as *Kitāb fī qaṭᶜ al-khuṭūṭ ᶜalā al-nisāb* and *Kitāb fī qaṭᶜ al-suṭūḥ ᶜalā nisbat.* See also Hogendijk 1985, 98; and Sezgin 1974, 142–43. Apollonius's *Conica* (*Kitāb al-makhrūṭāt*) and its various translations are discussed in Sezgin 1974, 136–43. The Banu Musa (Muhammad, Ahmad, and al-Hasan) and their works are mentioned in Ibn al-Nadīm 1970, 2: 637–38, 645–46; Hogendijk 1985, 1–30; and Souissi 1982, 412.

20. For the science of mechanics, see al-Fārābī 1949a; and Wiedemann 1970, 346–47. Al-Farabi divided mechanics into two sections, one based on arithmetic and the other on geometry. The only field in the first section is algebra, which used both arithmetic and geometric proofs. For mechanical subjects included in Books 8–10 of Vitruvius's architectural treatise, see Vitruvius Pollio 1914, 225–319. For the concept of *metis,* see Detienne and Vernant 1974.

21. Translated in Downey 1946–1948, 106–7. For Pappus's ninth-century Arabic translation, see Jackson 1972, 96–103.

22. Downey 1946–1948, 107; Kostof 1986, 63.

23. See part 4, nn. 6 and 8, above. In the late tenth century al-ᶜAmiri wrote: "Mechanics is a discipline that shares both mathematics and natural science. It enables one to bring forth hidden water from the interior of the earth and also to conduct water through water-wheels or fountains, to transport heavy objects with the application of little energy, to construct arched bridges over chasms, to erect other wonderful bridges over deep streams and to accomplish many other things, whose mention here would take up too much room"; translated in Rosenthal 1975, 66. In their classifications of knowledge such authors as al-Khwarezmi and Nasir al-Din al-Tusi continued to list mechanics among the mathematical sciences. For al-Khwarezmi's chapter on *ḥiyal,* in the *Mafātīḥ al-ᶜulūm* (Keys of sciences), circa 977, see Wiedemann 1970, 188; and Bosworth 1963.

24. Al-Bayhaqi's biographical entries are translated into German in Wiedemann 1970, 649, 653. Abu Hatim al-Muzaffar b. Ismaᶜil al-Isfizari, who was a contemporary of ᶜUmar Khayyam, said: "Geometry is the basis for architecture; that is why the geometer with his science constitutes the foundation. He is followed by the master builder who in turn is followed by the wage laborer [bricklayer]. The geometer commands the second [i.e., master builder] and the master builder commands the wage laborer, while the wage laborer busies himself with water and clay." Al-Qajini, who was trained in the practical rather than the theoretical branches of geometry, wrote: "The mason does not have the same significance as the architect and the architect not the same as the geometer. The geometer is Ptolemy, the architect is al-Battani, and my role is that of the mason." See also al-Ṭūsī 1964, 217.

25. For Shams al-Din Muhammad b. Ibrahim b. Saᶜid al-Ansari al-Sinjari, called Ibn al-Akfani, see Ibn al-Akfānī 1990, translated in Wiedemann 1970, 110–13. See also Taşköprizāde 1895, 406–11.

26. For the applied branches of geometry mentioned by these authors, see al-Hassan and Hill 1986, 263–64.

27. For the science of construction, see Taşköprizāde 1895, 406. Ibn al-Akfani's definition of this science is translated into German in Wiedemann 1970, 114–15. For al-Karaji's treatise titled *Inbāṭ al-miyāh al-khafīya* (Book on finding hidden waters), see al-Karajī 1973; and Vernet and Catalá 1970.

28. This lost work entitled *Kitāb al-aḥyā' wa al-athār* (Book of the living and monuments[?]) is cited in Wilber 1976, 31; and Bulatov 1988, 93.

29. For medieval Vitruvius manuscripts, see Krinsky 1967; and Conant 1968. The early fifteenth-century Vitruvius manuscript in Budapest, which once belonged to the duke of Milan, Francesco Sforza (1401–1466), and later to King Matthias Corvinus, *De Architectura* (MS Lat. 32, Bibliothecae Universitatis Budapestiensis, Budapest), is discussed in Hajnóczi 1991. This copy came back from Istanbul in 1877 when Sultan Abdülhamid II sent it with other manuscripts once belonging to the Biblioteca Corviniana as a diplomatic gift to Hungary.

30. Cited in Wiedemann 1970, 418; see also Sezgin 1974, 328.

31. Cited in Wiedemann 1970, 114–15; and Sezgin 1974, 373.

32. Ibn Khaldūn 1967, 3: 132.

33. Thabit b. Qurra's Arabic treatise, *Kitāb fī misāḥat al-mujassamāt al-mukāfīya* (Book on the mensuration of parabolic bodies), is contained in MS Arabe 2457, sec. 24, fols. 95–122, Bibliothèque Nationale, Paris, and lists three types of parabolic domes. The treatises in this Paris manuscript were copied in 969 by al-Sijzi; see Sezgin 1974, 264–72. Al-Sijzi's own treatise on measuring domes is in MS Reşit Efendi 1191, sec. 4, fols. 66–68, Süleymaniye Kütüphanesi, Istanbul; see Sezgin 1974, 331. For treatises on the mensuration of parabolas and paraboloids, see Suter 1986, 2: 369–491.

34. For various geometers who wrote on conic sections, see Souissi 1982, 412–13; and Hogendijk 1985, 59–62, 96–115. Muhammad b. Musa b. Shakir, one of the Banu Musa brothers attached to the ninth-century Abbasid court, was the first to write an introduction to the conical forms that simplified Apollonius's treatise for practical use. This was followed by a stream of treatises on conics between the ninth and eleventh centuries by such mathematicians as Thabit b. Qurra, al-Mahani, Ibrahim b. Sinan, al-Sijzi, and Ibn al-Haytham; see Souissi 1982; and Rashed 1993.

35. For the device known as the conic compass, which facilitated drawing the conic sections, see Hogendijk 1985, 35–36; Woepcke 1874; Wiedemann 1984; and Yushkevich 1964, 288.

36. al-Jazarī 1974, 196–98. Al-Jazari wrote: "I made an instrument for that to facilitate the determination of the required centre-point, and the determination of all the angles in [general] use, acute and obtuse. This is [the method]." He then continued with a description of this

drafting instrument, but it is unlikely that he invented it, given the derivative nature of his treatise that freely draws on earlier works on the same subject, such as the book of ingenious devices by one of the Banu Musa brothers; see Ibn Mūsā b. Shākir Muḥammad 1979. Al-Jazari seems to have been a technologist rather than a professional mathematician; inventing such an instrument would have required extensive mathematical training. Not enough is known about the history of Islamic drafting instruments to be able to determine when the one described by al-Jazari was invented. For instruments, see part 4, n. 35, above.

37. This instrument is reconstructed in Bulatov 1988, 328; see MS Persan 169, sec. 24, fol. 191, Bibliothèque Nationale, Paris. It is unclear which treatise by Ibn al-Haytham the anonymous author was referring to; this may have been a lost work of the mathematician who extensively dealt with conic sections throughout his career. The anonymous author says that according to the inventor of the instrument one could draw complex conic sections with its aid, but he admitted his unfamiliarity with this technique. It is also possible that the anonymous author was referring to the concluding chapters of Ibn al-Haytham's *ʿUqūd* treatise, which dealt with conic sections, rather than to a separate treatise on the construction of that particular right triangle. For Ibn al-Haytham's works on conics, see Souissi 1982, 413.

38. See, for example, the "how-to" instructions in MS Persan 169, sec. 24, fol. 194, Bibliothèque Nationale, Paris.

39. al-Jazarī 1974, 191–95.

40. Ibid., 195.

41. Ibid., 192.

42. For the Damascene geometer, see Wiedemann 1970, 114 n. 1. The role of practical geometry is discussed in Ibn Khaldūn 1967, 2: 363.

43. Ibn Khaldūn 1967, 2: 360–61.

44. See Plessner 1960, 994: "Apollonius of Perge appears in the biographical sources . . . almost invariably with the epithet al-Nadjdjār (the carpenter), the origin of which has not yet been explained satisfactorily. . . . Also Euclid was called the geometer, and . . . Ibn al-Qifṭī calls him al-Nadjdjār in the heading of his article, but states afterwards that Euclid was a carpenter by vocation." In medieval Europe, Euclid was invoked as the father of masonry; see Bucher 1972, 532.

45. Caʿfer Efendi 1987, 27, 30. For the garden workshops of the Topkapı Palace, see Necipoğlu 1991, 46–50, 207–8. The close relationship and rivalry between music and architecture at the Ottoman court is discussed in Necipoğlu 1990a.

46. Caʿfer Efendi 1987, 28.

47. Ibid., 32.

48. Ibid., 28.

49. Ibid., 22–23.

50. Ibid., 30–31.

51. Ibid., 67–68.

52. Ibid., 34.

53. Konyalı 1948, 72.

54. Sāʿī 1989, 52–56, 141–42, fols. 2b–3a; translation mine.

55. Evliyā Çelebi 1896–1897, 157–59; Loḳmān, *Sūrnāme,* MS H. 1344, fol. 189b, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul. The description of the model paraded in 1675 from the late seventeenth-century *Sūrnāme* of Abdi is cited in And 1982, 86. For the use of architectural models in Ottoman architectural practice and the reproduction of a miniature showing the model of the Süleymaniye mosque paraded in 1582, see Necipoğlu 1986.

56. Loḳmān, *Sūrnāme,* MS H. 1344, fols. 171b–172a, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul. The quotation of Filippo Pigafetta (1533–1604), himself a mechanic, is cited in Wilkinson 1988, 474. For Sinan's jurisdiction over building- and decoration-related crafts, see Necipoğlu 1992a, 211.

57. Qaisar 1988, 14.

58. Translated in Begley and Desai 1989, 267, 270.

59. For these Mughal mathematical treatises and further bibliography, see ibid., xli–xlviii, 266–75.

60. See ibid., 275.

61. Translated in Thackston 1989, 159.

62. For the *Haft Paykar,* included in the *Khamsa* (Five epic poems), see Niẓāmī Ganjawī 1991–1992, 141–42. In this work Nizami described Sinimmar, the legendary builder of the Khawarnaq castle, as skilled in drawing, preparing talismans, and making astrolabes; see idem, 59. For the reference to Farhad in *Khusraw wa Shīrīn,* see idem, 216–17. The architect Badr al-Din Tabrizi is mentioned in Aflākī 1986–1987, 2: 159, 287–88. For the image of the medieval Islamic architect in literary sources, see also Bulatov 1988.

63. Vitruvius Pollio 1914, 5–6, 11–12.

64. Ibid., 6.

65. For Baha' al-Din ʿAmili, see S. H. Nasr, "Spiritual Movements, Philosophy and Theology in the Safavid Period," in Jackson and Lockhardt 1986, 666–69; and al-ʿĀmilī [18—?]. Professional mathematician-engineers seem to have been more frequently involved in construction projects during the early Islamic era, especially during the foundation of such new caliphal capitals as Baghdad and Samarra.

66. For a summary of the views of Soviet scholars on the mathematical knowledge commanded by architects, see Bulatov 1988.

67. al-Khwārezmī 1831, 3, 71. The contents of al-Khwarezmi's treatise are discussed in Bulatov 1988, 83–88; and Dold-Samplonius 1993, 2–3.

68. For Abu Kamil's treatise known from a Hebrew translation, see Sacerdote 1896; Suter 1986, 1: 247–75; Sezgin 1974, 277–81; and Dold-Samplonius 1993. For the arithmetic treatise of al-Buzjani, see al-Būzjānī 1971; and Saidan 1974.

69. Bosworth 1963, 98–99.

70. Cited in Mez 1937, 104–5. For the culture of the Buyid court, see Kraemer 1986; and Mottahedeh 1980.

71. For the Timurid organization, see O'Kane 1987, 40: "The work of supervision on a large-scale project could be divided up on successive hierarchical levels, with amirs and high government officials specifically receiving superintendencies (*sarkārhā*)." He added that in some cases architects *(miʿmār)* acted in a purely administrative capacity. The Ottomans are discussed in Mayer 1956, 19. For the administrative organization of the construction industry in Mughal India, see Qaisar 1988, 5–15.

72. For the works on applied arithmetic by al-Karaji and Ibn al-Haytham, see Busard 1968, 69; Dold-Samplonius 1993, 6–7; and al-Karajī 1878–1880. For the science of *misāḥa,* see al-Farābī 1949a. Ibn Khaldun grouped mensuration among the geometric sciences concerned with "quantities [measurements]" rather than among the arithmetic sciences "concerned with numbers" just like Caʿfer Efendi, the author of the *Risāle-i Miʿmāriyye;* see Ibn Khaldūn 1967, 3: 118–35; and Caʿfer Efendi 1987, 30–31, 83. For the practical uses of *misāḥa* and an introduction to the major texts in this field, see Schirmer 1993.

73. Schirmer 1993. For al-Kindi's geometric works, see Ibn al-Nadīm 1970, 2: 619; and Sezgin 1974, 258. Barbaro's commentary on Book 3 of Vitruvius, which deals with proportions, summarizes the propositions of "Alchindo" on the rules of proportion; see Barbaro 1567, 103–7.

74. For Abu Bakr's Latin translation, see Sezgin 1974, 389–91; Schirmer 1993, 137; Suter 1900, no. 224; and Busard 1968.

75. I am grateful to Dr. Yvonne Dold-Samplonius for sending me copies of her forthcoming and published articles on al-Kashi's mensuration of the muqarnas and dome. For the quoted passage, see Dold-Samplonius 1992a, 193. For al-Kashi's chapters on mensuration, see also idem 1992b; idem 1993; and idem forthcoming. Another recent analysis of al-Kashi's chapter on the muqarnas is in Özdural 1990.

76. Ghiyath al-Din al-Kashi's role (together with Mawlana Muʿin al-Din al-Kashi) as building supervisor (*dar tartīb-i ān binā'*) is mentioned in Khwāndamīr 1954, 4: 21. Al-Kashi's letter (MS 2916, Kitabkhana-i

Masjid-i Sipahsalar, Tehran) is cited in Sayılı 1960, 282.

77. See Dold-Samplonius 1992a, 193–94.

78. Chardin 1711, 2: 80. For the full quotation, see part 1, p. 44, of the present volume.

79. Komaroff 1991, 610–11. Referring to al-Kashi's treatise on arithmetic, Rogers rightly asked: "How far was this prescriptive and how far a commonplace example to explain a series of mathematical functions? Kāshī was certainly not an architect, nor can mastery of such mathematical functions have been an essential part of the architect's training." He concluded, "Whatever the future may show the required demonstration that Timurid architects were mathematicians or that metrology has an important contribution to make to the history of Timurid architecture is not yet to hand"; Rogers 1989, 134–35. For the mathematical explanation of the mason's method, see Dold-Samplonius forthcoming; idem 1992a, 220–26; and Özdural 1990.

80. Vitruvius Pollio 1914, 5–6, 11–12.

81. MS Bāb-ı Defterī Baş Muhasebe, Binā Emīni (D. BŞM. BNE.), no. 15999, Başbakanlık Arşivi, Istanbul. I plan to analyze this document in a forthcoming study.

82. See López de Arenas 1912; and idem 1966.

83. For the lower status of mechanics in Renaissance Europe, see Wilkinson 1988, 472–74. The practical geometry of medieval master builders and artisans may have been a humble science, but it was, as Kostof pointed out, "the vernacular of the same language that was used by the intelligentsia." In the end "what distinguished the [medieval] architect from the master mason would be exactly his mastery of the theoretical implications of geometry, which is why the architect could find no loftier portrait for himself than to be represented as a geometrician with compass and measuring rod in hand"; see Kostof 1986, 79–80.

84. Bucher 1972, 528, 532; Harvey 1971, 36, 41.

85. Active in Barcelona, Abraham bar Hiyya was involved in translating the masterpieces of Arab science into Latin. For Abraham bar Hiyya and Fibonacci, see Busard 1968, 67, 85; and Lindberg 1978b.

86. Sacerdote 1896, 174–76; Suter 1986, 1: 247–75; Woepcke 1855, 221. See also Schirmer 1993; and Sezgin 1974, 280, 390.

87. Ibn ʿAbdūn 1981, 172–73. For the translation movement, see Lindberg 1978b.

88. Cited in Summers 1987, 254; and Victor 1979, 7–11.

89. Translated in Victor 1979, 7–11. Gundissalinus used the expression "secundum geometriam practicans" to define the artist and artisan; see Simson 1974, 33 n. 33. See also Wilkinson 1988, 470–72.

90. For the medieval status of the mechanical arts, see Sternagel 1966, 27–33; Wilkinson 1988, 470–72; Ovitt 1983; and Summers 1987, 262–65.

91. Cited in Wittkower 1988, 151. For Grosseteste, see Crombie 1953. For the quotation from Villard, see Bucher 1979, 121. Medieval European practical geometries are discussed in Victor 1979.

92. Cited in Bucher 1979, 14.

93. See Kepler 1939; and Field 1979. Kepler defined congruence as follows: "Congruence takes one form in the plane and another in space. In the plane there is congruence when individual angles of several figures come together at a point in such a way that they leave no gap"; translated from the second book of *Harmonices Mundi* in Field 1979, 113. The titles of Kepler's five books give an idea of his grand scheme: Book 1, *The Regular Figures Which Give Rise to Harmonic Proportions;* Book 2, *Congruence of Harmonic Figures;* Book 3, *The Origin of Harmonic Proportions in Nature and Differences between Things Appertaining to Music;* Book 4, *The Harmonic Configurations of the Rays of Stars and the Earth, and Their Effect in Determining the Weather and Other Natural Phenomena;* and Book 5, *The Most Perfect Harmony in the Celestial Motions and the Origin from Them of Eccentricities, Semidiameters, and Periodic Times.* For the cosmic symbolism of the Platonic solids in the Renaissance, see Pacioli 1509.

94. For the practical geometries of these authors, see Bucher 1979, 34. Roriczer's short fifteenth-century pamphlet on constructive geometry, *Geometria Deutsch,* is translated into English in Shelby 1977, 113–23.

95. See Dürer 1970; and Schröder 1980, 9–12.

96. Dan Pedoe commented on Dürer's construction of the pentagon: "The medieval constructions of regular polygons were, of course, approximate, but they were, and had to be, simple, preferably not even calling for a change in the opening of the compasses, which had no device to recapture an opening, once it was changed. . . . Dürer knew Euclid, but he does not give Euclid's construction for a regular pentagon, which is a theoretically exact one. . . . Euclid makes no attempt to trisect a given arc, and Dürer knew that this was impossible. . . . Dürer does give *approximate* constructions for the trisection of an arc"; Pedoe 1976, 69. There are similar pentagon constructions in the *Aʿmāl wa ashkāl* (see Bulatov 1988, 322, fig. 22) and in *Geometria Deutsch* (see Shelby 1977, 113–23).

97. Kemp 1978; idem 1990; Kuhn 1990.

98. The impact of Ibn al-Haytham's optical treatise in Europe is discussed in Ibn al-Haytham 1989, 2: xi, 97; Lindberg 1967; and Summers 1987, 74.

99. For the development of perspective in Renaissance Europe, see Panofsky 1924–1925; Kubovy 1986; Damisch 1987; and Jay 1988, 3–23.

100. Summers 1987, 316.

101. Ibid., 73.

102. For a description of the contents of the manuscript, see Blochet 1905–1934, 2: no. 772, 41–47; and Richard 1989, 183–87.

103. For Seljuq and Mongol science, see Kennedy 1968; sciences in the Timurid period are discussed in idem 1986. For Safavid sciences, see Winter 1986.

104. For the commentary written in Mosul, see Chorbachi 1989, 752–54. It was Bulatov who first linked the Persian translation in Paris with Ibn ʿIraq and the eleventh-century Khwarezmian court; see Bulatov 1988. Kubanani Yazdi's postscript invokes the names of his master Shams al-Din Abu Bakr Shah b. Najm al-Din Mahmud Shah b. Hajji Taj al-Din Kudak and of his deceased brother Shaykh Najm al-Din Mahmud. The latter had written a commentary on the *Almagest* and a gloss on the Greek mathematician Menelaus's *Spherics* in addition to other works. It was he who had begun copying al-Buzjani's text but died before completing this enterprise; see Sezgin 1974, 321–25; and Richard 1989, 186–87. For the court of Khwarezm, see Bosworth 1978. Ibn ʿIraq's works are listed in Sezgin 1974, 338–41. The medieval Persian text in Paris has been adapted to modern Persian in al-Būzjānī 1990–1991.

105. For the Arabic text in Istanbul, see Krasnova 1966, 42–55. For surviving al-Buzjani manuscripts, see part 4, n. 13, above.

106. MS Persan 169, sec. 7, fols. 49v–63, Bibliothèque Nationale, Paris. For a description, see Blochet 1905–1934, 2: no. 772, 42; and Richard 1989, 184.

107. MS Persan 169, sec. 10, fols. 70v–89, Bibliothèque Nationale, Paris.

108. MS Persan 169, sec. 16, fols. 108–118, Bibliothèque Nationale, Paris; idem, sec. 19, fols. 124v–138.

109. Fuat Sezgin suggested that the Abhabuchr (Abu Bakr) mentioned in the Latin text may have been the little-known author of the *Risāla fī misāḥat al-ashkāl* (Treatise on the mensuration of figures), an Abu Bakr al-Qadi who lived in the first half of the eleventh century. However, Abhabuchr's identity has not been confirmed. Neither Gerard of Cremona's abridged Latin text nor the *Risāla* includes the last section on applied mechanics appended to the longer Persian treatise in Paris (*Aʿmāl*) whose author may have been the same Abu Bakr. Abu Bakr al-Qadi's four-part treatise (MS 3439, sec. 17, fols. 127v–134, Fatih Kütüphanesi, Istanbul) is cited in Sezgin 1974, 386; for the four-part Latin text, see idem, 389–91.

110. Abu Bakr is cited in MS Persan 169, sec. 24, fols. 187r, 189r, Bibliothèque Nationale, Paris.

111. MS Persan 169, sec. 24, fol. 189r, Bibliothèque Nationale, Paris (fig. 32 in Bulatov 1988, 327); MS Persan 169, sec. 24, fol. 187r, Bibliothèque Nationale, Paris (fig. 26 in Bulatov 1988, 324). The tabulated table is on

fol. 184r; see Bulatov 1988, 322.

112. For one such solution proposed by the author, see MS Persan 169, sec. 24, fol. 190r, Bibliothèque Nationale, Paris.

113. Bulatov 1988, 315–40; Golombek and Wilber 1988, 1: 159. See also Holod 1986; and idem 1988. One of the patterns that may have been added to the treatise in the Timurid period is the last one, which has no accompanying text (see fig. 113a in the present volume). But even this last pattern is not inconsistent with an early medieval repertory; for comparable examples of swastika compositions in Anatolian Seljuq monuments, see Mülayim 1982, 185, 192, 232.

114. Blochet 1905–1934, 2: no. 772, 41–47.

115. They wrote, "Since this architectural decoration dates from the period 1180–1230 A.D., we may conclude that knowledge about the Pentagonal Seal had by that time filtered down to artisans, so that the material presented in folio 180a may be dated to before 1200 A.D., circa 1180–1230 A.D."; see Chorbachi and Loeb 1992, 301–4. This is, however, a hypothetical date, given that the pre-thirteenth-century examples of geometric ornament from monuments in the Baghdad region have completely disappeared. It is therefore not possible to firmly establish when the patterns seen in the anonymous treatise first came into use in architectural decoration. Chorbachi seems inclined to date the anonymous treatise to Iraq around the late twelfth or early thirteenth century, given the revived interest in those years in al-Buzjani's practical geometry on which Kamal al-Din Musa b. Yunus b. Manᶜa, known as Ibn Manᶜa, wrote a commentary in Mosul; see Chorbachi 1989, 752–54. Alpay Özdural proposed an early thirteenth-century date, given the similarity between the drafting instruments (see figs. 107, 108) depicted in the anonymous treatise and in al-Jazari's early thirteenth-century manual on ingenious devices written in Diyarbakır; see Özdural 1995, 70 n. 46.

116. MS Persan 169, sec. 24, fols. 185v, 187v, 190r, Bibliothèque Nationale, Paris.

117. MS Persan 169, sec. 24, fol. 187v, Bibliothèque Nationale, Paris.

118. MS Persan 169, sec. 24, fol. 190r, Bibliothèque Nationale, Paris.

119. MS Persan 169, sec. 24, fols. 183v–184, Bibliothèque Nationale, Paris.

120. It was the Persian mathematician and poet ᶜUmar Khayyam (d. circa A.D. 1130) who perfected such cubic equations, which have been regarded as the highest achievements of Muslim mathematicians, in his famous algebra, *al-Jabr;* see Sarton 1927–1948, 1: 759–61. For a mathematical text of ᶜUmar Khayyam addressing the practical concerns of artisans, see Özdural 1995.

121. For the Indian sources, see Yushkevich 1964, 99. See also Chorbachi 1989, 764–71, where the algebraic analysis of this geometric construction and its use in Islamic architectural decoration are discussed. The names given by contemporary Iranian craftsmen are cited in Orazi 1976, figs. 79–81; and Firishtah Nazhad 1977, 9.

122. Jones 1982, 69.

123. For the triangulation methods and harmonic divisions of polygons shown in the anonymous treatise and the special importance assigned to the pentagon (which is not as prominent in the Topkapı scroll), see Bulatov 1988, 90, 315–24, 339. The irregular patterns in this treatise may reflect a misunderstanding on the part of the copyist, who made several errors. One of these errors was noted by Chorbachi: "Clearly this was a copyist's error, which in turn tells us something else about this unique manuscript: that it is copied and thus there must have been another manuscript like it. My main hope here is that the original manuscript has survived somewhere and will be recognized or discovered one day. Using another manuscript, one can resolve some of these textual problems"; see Chorbachi 1989, 777. It is unclear whether the original manuscript was written in Arabic or Persian.

124. By adding a representational dimension to the geometric problem of proportionally dividing a plane, Escher's zoomorphic tilings animated the nonrepresentational star-and-polygon compositions of "Moorish" patterns, whose purely abstract qualities had fascinated so many nineteenth-century European theorists of ornament. Escher regretted that Islamic geometric patterns based on this principle were limited to abstract shapes: "Altogether it is doubly unfortunate that the only people obviously intrigued by this possibility—the Moors—were not allowed to proceed beyond abstractions"; see Coxeter et al. 1986, 16.

125. It is not surprising that Escher, too, did not limit himself to plane tilings but also experimented with the regular division of space into closely packed congruent three-dimensional cells, or space tilings. See, for example, his drawing entitled *Cubic Space Division* in Coxeter et al. 1986, 6, fig. 4.

126. Al-Kashi's discussion of the muqarnas is interpreted in Golombek and Wilber 1988, 1: 164–65. For recent studies and an English translation, see Özdural 1990; Dold-Samplonius 1992a; and idem forthcoming. See also "The Muqarnas" by Mohammad al-Asad in the present volume.

127. The origin of the muqarnas has puzzled scholars from the nineteenth century onward. Diez wrote in 1938, "The muqarnas was not invented by a people but grew out of the soil of a common Weltanschauung"; see Diez 1987, 153–54. According to Grabar, "So far as is known, the origins of the muqarnas probably lie in almost simultaneous but apparently unconnected developments in north-eastern Iran and central North Africa"; see Grabar 1978, 176.

128. Ibn Jubayr 1907, 253. This passage is translated and discussed in Tabbaa 1986, 230–35: "The *qarbasa* craft has exhausted its resources in this *minbar,* for I have not seen in another country a *minbar* which resembles its shape and the uniqueness of its manufacture. . . . It rises like an enormous crown above the *mihrab* until it reaches the ceiling. Its top part is arched and open with balconies. It is all inlaid with ivory and ebony, and this inlay work continues to the *mihrab* and beyond the *qibla* wall without any apparent division, so that the eyes enjoy one of the most beautiful sights in the world." For the term *muqarbaṣ* or *muqarbas,* used as a synonym for muqarnas in the western Islamic world, see Fernández-Puertas 1993. The confusion between *muqarnaṣ* and *muqarbaṣ* is noted in the glossary of Ibn Jubayr 1907, 44. For the etymology of muqarnas, see "The Muqarnas" by al-Asad in the present volume; and Dold-Samplonius 1992a, 197–200.

129. MS Persan 169, sec. 24, fol. 180v, Bibliothèque Nationale, Paris (fig. 2 in Bulatov 1988, 316). Among mathematical treatises on the subject of proportion written around the same time were al-Buzjani's *Risāla fī al-nisab wa al-taᶜrīfāt* (Epistle on ratio and proportion) and the Baghdadi mathematician Abu ᶜAbd Allah Muhammad b. ᶜIsa b. Ahmad al-Mahani's (circa 825–888) *Risāla fī al-nisba* (Epistle on proportions) and *Risāla fī mushkil min amr al-nisba* (Epistle on complex proportions); for these works and other works on proportion by Ibn al-Haytham and ᶜUmar Khayyam, see Sezgin 1974, 100, 260–62, 324. See also epistle 6 on ratio and proportion, in Ikhwān al-Ṣafā' 1928, 1: 181–94, discussed in part 5.

130. See Ibn Khaldūn 1967, 3: 360–61, 365: "Another technique of construction is decoration and ornamentation. Thus, figures formed of gypsum are placed upon the walls. [The gypsum] is mixed with water, and then solidified again, with some humidity remaining in it. Symmetrical figures are chiseled out of it with iron drills, until it looks brilliant and pleasant. The walls are occasionally also covered with pieces of marble, brick, clay, shells [mother-of-pearl], or jet. [The material] may be divided either into identically shaped or differently shaped pieces. The pieces are arranged in whatever symmetrical figures and arrangements are being utilized by the [various artisans], and set into the quicklime [with which the walls have been covered]. Thus, the walls come to look like colorful flower beds." See also López de Arenas 1912 (1633), fol. 23r.

131. Dost Muhammad's description of the Safavid artist Master Kamal al-Din Husayn's geometric patterns is translated in Thackston 1989, 349. See also al-Jazarī 1974, 191.

132. See, for example, Evliya's description of the marble gate of the Yeşil Cami in Bursa with multilayered (*ḳat ender ḳat*) interlaces of *girih, islīmī,* and *rūmī* patterns designed in a wonderful manner (*ṭarz-i ʿacīb ve ṭavr-i ġarīb*) in Evliyā Çelebi, *Seyāḥatnāme* (Book of travels), vol. 2, MS B. 304, fol. 224v, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul. He described the minbar of the ʿAla' al-Din mosque in Sinop as having three superimposed layers (*üç ḳat birbiri altında*) of interlaced pattern, a wonderful (*ʿibretnümūn*) work whose design manifested miraculous saintly powers (*evliyā ullāhıñ iẓhār-ı kerāmetidür*) and astonished the viewer (*engüşt berdehān*). Its designer had so skillfully fitted together small pieces of marble that even the scrutinizing gaze (*imʿān-i naẓar*) of experts could not decipher the joints that appeared continuous; see idem, fol. 246r. Evliya described the minbar and mihrab of the Sultan Hasan mosque in Tabriz, with its intricate interlacing of *muḳarnas, islīmī, rūmī,* and geometric patterns, as a work whose creator's talent approached the level of licit magic (*siḥr-i mübīn mertebesi*); see idem, fol. 299r. Similarly, the Kızıl Medrese in Sivas had a marble gate with seventy to eighty layered interlaces characterized as a wonderful work (*ʿibretnümūn*) approaching the level of licit magic (*siḥr-i mübīn*); see idem, fol. 75r.

133. Caʿfer Efendi 1987, 34.

134. See Rahman 1965.

135. Bryson 1983, 87–131.

136. For Viollet-le-Duc, see the preface in Bourgoin 1873a. Yve-Alain Bois has recently argued that the French painter Henri-Emile-Benoît Matisse (1869–1954) was aiming at a similar "blindness of vision" by his rejection of monocular perspective. His paintings encouraged "a distracted glance, a peripheral glance, a glance dispossessed of its force of concentration." Bois suggested that this is why Matisse was so seduced by the labyrinthine optical effects of Islamic architectural revetments and the decorative arts; see Bois 1993. For a similar "madness of vision" in Baroque art, see Jay 1988, 16–20.

PART 5. GEOMETRY AND AESTHETIC THEORY

Euclid alone has looked on Beauty bare.

—Edna St. Vincent Millay, *The Harp-Weaver*

CHAPTER 10. THE AESTHETICS OF PROPORTION AND LIGHT

Since architecture and the decorative arts were classified as part of applied mechanics, rooted in a shared language of practical geometry, their principles were expounded in mathematical treatises that complemented oral traditions and workshop drawings. Despite their high status throughout Islamic history, these fields did not generate a separate body of nonmathematical theoretical writing from which one could deduce their aesthetic principles. By contrast a considerable theoretical literature existed on music, literary criticism, and to a lesser extent on calligraphy, which together with literature was classified as part of the trivium (grammar, logic, rhetoric). The concept of taste (*dhawq*), defined as the power of aesthetic perception, was a mysterious emotional quality by which the heart and soul could be moved, a subjective quality that nevertheless required objective standards.[2] These standards were most clearly defined in literary criticism. Music (a science with both theoretical and practical branches subsumed under the quadrivium) had a questionable status in some puritanical circles, but it, too, received theoretical elaboration in the writings of such major philosophers as al-Kindi, al-Farabi, and Ibn Sina and later thinkers who explored its effects on the soul.[3]

In both medieval Europe and in the Muslim lands the realm of "art" had broad horizons encompassing what we think of nowadays as technology and artisanry. The medieval theory of art (*ars*) was, therefore, "first and foremost a theory of craftsmanship."[4] The arts in the Islamic world were generally subsumed under umbrella terms such as *fann* and *ṣanʿat* that referred to all fields of expertise or skill in the crafts and sciences alike. Consequently, theoretical writings on poetics, music, and calligraphy are filled with references to the visual arts and architecture, reflecting the common semantic field of crafts. Jerome W. Clinton, in his analysis of the prosodist Shams-i Qays's (fl. 1204–1230) Persian manual of versification, said that "from the point of view of the literary critic, at least, poetic esthetics and the esthetics of art were co-extensive." He drew attention to the frequent use of craft metaphors in literary criticism where poetic composition is often compared to weaving a patterned brocade, designing a rhythmic arabesque, or stringing a necklace according to the rules of measured composition (*ta'līf*) and proportion (*tanāsub*). The Ottoman theorist of poetry Muslih al-Din Mustafa Sururi (1491–1562), who used such craft metaphors, compared the ornamental arts of poetry (*ṣanā'i-yi şiʿrīye*) to the wall paintings (*naḳş*), tile work (*kāşīkār*), and pomp (*alayiş*) of a house, referring to the art of homophony as *tarṣīʿ* (lit., "tarsia," or "to inlay with pearls and precious stones").[5]

In addition to theoretical writings on literature and music, which provide valuable glimpses of visual aesthetics, philosophical texts also were richly imbued with aesthetic notions. As in medieval Europe, which did not have an aesthetics independent of scholastic philosophy, in the Islamic world concepts of beauty often were embedded in metaphysical discussions. The relevance of such philosophical texts for architectural and artisanal production has not yet been explored systematically. Conceptual categories provided by Islamic intellectual history have been ignored by art historians who focus on the hard data of archaeology,

epigraphy, historical sources, and standard religious texts. The positivistic formal studies that dominate the field of Islamic art and architecture (which ultimately grew out of nineteenth-century Orientalist archaeology and museology) treat buildings and objects as items to be cataloged in terms of geographic regions, style, typology, inscriptions, decorative techniques, and factual data on artists and patrons. The few interpretive studies emphasize the political and ideological contexts of art and architecture, largely overlooking more elusive questions about aesthetic philosophy.[6]

This explains why no sourcebook has been compiled on visually relevant aesthetic writings from the Islamic world, comparable to such anthologies as Julius von Schlosser's *Die Kunstliteratur,* 1924; Edgar de Bruyne's *Etudes d'esthétique mediévale,* 1946; and Paul Frankl's *The Gothic: Literary Sources and Interpretations through Eight Centuries,* 1960. In the next two chapters I will discuss some definitions of ideal beauty together with psychological theories of the processes of artistic creation and visual perception scattered in various Islamic texts. Of course, many other relevant texts could be cited for their implications about visual aesthetics in general and geometric abstraction in particular. The ones I have chosen, regardless of whether they exercised a direct influence on builders and decorators, provide fragmentary glimpses into widespread aesthetic sensibilities that acted as a general backdrop against which visual idioms were formulated and reformulated in specific historical contexts.

Medieval aesthetics in the Latin West, Byzantium, and the Islamic world built upon a shared heritage received from classical antiquity, a heritage that was infused with the monotheistic transcendental orientations of Islam and Christianity. Just as medieval Islamic science was rooted in the late school of Alexandria, the philosophical speculations of Muslim thinkers who attempted to reconcile Plato and Aristotle with Islam were inspired by the classical tradition. The philosophical sciences became widely disseminated between the ninth and late tenth centuries, trickling down in popularized form to the urban culture of major Islamic cities, much like the diffusion of the mathematical sciences at that time. After the consolidation of the Sunni revival in the eleventh century, however, orthodox refutations of philosophy multiplied. Aesthetic theories tinged with Neoplatonism were now revised according to dominant orthodox sensibilities, distilled in popularized form through Sufism, and assimilated into the mainstream of medieval Islamic culture.

The late tenth-century *Rasā'il* of the Brethren of Purity seems to have played an important role in popularizing aesthetic concepts developed in the writings of such philosophers as al-Kindi and al-Farabi. The Brethren spread their central teaching (the salvation of souls from the defilement of matter by spiritual purification so that they might return to their true home by celestial ascent) among the elite and masses alike, in particular addressing artisans and the generally educated common people. To this end they expounded their ideas in a more popular idiom than that of the philosophers. As we have seen, the *Rasā'il,* which constituted an encyclopedia of the philosophical sciences, was also popular in Sunni circles despite the heterodox Shiʿi leanings of its authors associated with the Buyid court in Baghdad.[7]

The fifty-two epistles, in which mathematics and astrology occupy a primary position, are an eclectic blend of Pythagorean (Pythagoras is referred to as a monotheistic sage from Harran) and Neoplatonic physicomathematical ideas merged with Babylonian astrology and Hermetic doctrines. The first of the fourteen mathematical epistles deals with arithmetic, "the science of number" that is "the root of the other sciences, the fount of wisdom, the starting point of knowledge, and the origin of all concepts." This is followed by the epistle on theoretical geometry (differentiated from the practical geometry of the arts and crafts) that is similarly defined as a gateway to superior levels of theoretical understanding. Mathematics is thus presented as the threshold of intellectual insight along the pathway of progressive ascent toward the highest level of knowledge, metaphysics. The remaining mathematical epistles address such subjects as astronomy, music, geography, logic, "numerical, geometric, and harmonic ratios," and the arts and crafts. According to the Brethren mathematics plays a central role in the composition of the universe. Moreover, the relation of the indivisible unique God to the multiplicity of the universe (created as an eternal emanation of light) corresponds to the relation

of the number one to other numbers.[8]

The Brethren's cosmology echoes the emanationist worldview of earlier Arab philosophers such as al-Kindi and al-Farabi. As Majid Fakhry has shown, that worldview was inspired largely by the Neoplatonist philosopher Plotinus's (205–270) doctrine of emanation expounded in the *Enneads*. An abridged version of that work (the apocryphal *Theology of Aristotle* in which extracts from Plotinus appear as the culmination of Aristotle's *Metaphysics*) had been translated into Arabic for al-Kindi as early as the mid-ninth century. Attributed to Aristotle, Plotinus's doctrine of the One (the First Cause, or Pure Light) that generates the whole order of the universe through an emanation of the light of Reason (also discussed in Proclus's *Elements of Theology*) proved to be so appealing that it was conflated with the Islamic notion of an utterly transcendent unique God. The Plotinian theory of the cosmos as a continuum with a center—the One—that is transcendent and unknowable, but whose power emanates outward in such a way that it progressively diminishes as it approaches the outer extremes of the universe, would be divested of its pagan connotations and adapted to the monotheistic theologies of the Muslim and Christian worlds. It inspired the Muᶜtazili and Shiᶜi atomistic cosmology in which the earthly realm of accidents is dominated by a hierarchy of superior forces emanating from transparent celestial bodies, divested of matter with their dazzling lucidity and luminous purity. In this hierarchical scheme, the rational human soul appeared as an incorporeal substance capable of mediating between the intelligible realm of reason and the sensible realm of matter. Just as it could descend downward to the ignoble corporeal world of the senses, it could also direct its longing gaze upward toward the resplendent beauty of the intelligible world, infused with brilliant light.[9]

The Brethren of Purity described the splendor of that world by referring to the Pythagorean notion of the music of the spheres:

> If one establishes the measure of [musical] time by the regular, harmonious and proportionate succession of motions and silences, the notes resulting will be comparable to the notes produced by the movements of the spheres and the heavenly bodies and will be in concordance with them. Thus doing, the individual soul, that inhabits the world of generation and corruption, will recall the beatitude of the world of spheres and the felicity of souls who are there above . . . celestial bodies are more transparent than glass, more polished than a mirror. They touch, brush against each other, rub and resound as iron and copper resound. Their notes are concordant and harmonious; their melodies are well-balanced.[10]

The notes of terrestrial music imitate those of the celestial realm, causing the human soul to rejoice in their proportional and harmonic relationships to which its substance corresponds. In other words, aesthetic pleasure arises when the soul (subject to the same proportions that govern the cosmos) finds its own inner harmony duplicated in its object, leading it to remember with longing the music of the spheres to which it had once been exposed. The epistle on love and ideal beauty argues that one loves only beauty (*al-ḥusn*), a natural emotion that makes the ear and the eye long for harmonious sounds and compositions.[11]

This concept of the soul's innate love of beauty, which as we shall see was repeated in many later Islamic texts, once again can be traced back to Plotinus's *Enneads* where the beautiful is defined in emotional terms as that which induces wonderment, longing, delight, and love because of its kinship with the soul. Such philosophers as Ibn Sina and Ibn Hazm (994–1064) also discussed beauty as an object of love; the latter wrote: "As for what causes love in most cases to choose a beautiful form to light upon, it is evident that the soul itself being beautiful, it is affected by all beautiful things, and has a yearning for perfect symmetrical images; whenever it sees any such images, it fixes itself upon it; then, if it discerns behind that image something of its own kind, it becomes united and true love is established."[12]

Hearing and sight, the noblest of the five senses, were regarded by the Brethren as most capable of communicating to the soul a sense of pure aesthetic pleasure that cannot be articulated by words. The most pleasing proportions, they argued, echo the harmony of the heavenly spheres,

which provide archetypes for the corporeal world of generation and corruption. Just as the kinship between the soul and musical harmony could cause the former to find pleasure in measured rhythms, so did the soul marvel at harmoniously composed visual forms:

> Since the substance of the soul is of the same nature as that of harmonic numbers and corresponds to them, when the beats of the rhythms presented by the musician are measured, when in these rhythms the periods of beats and silences are proportionate, human nature takes delight in them, the spirit rejoices and the soul experiences happiness. All this is because of the resemblance, the relation and kinship which exist between the soul and musical harmony. It is the same when the soul marvels at the beauty of countenances and the ornament of natural things; for the beauty of the natural beings arises from the harmony of their constitutions and the beauty with which their various parts are composed together.[13]

In their epistle on music the Brethren stated that their goal was not to teach the practice of music but "to make known the science of proportions and the modality of harmony, the knowledge of which presides at the mastery in all the arts."[14] They devoted a whole epistle to the subject of ratio and proportion, arguing that geometry provides the shared basis of every art and that no art can achieve the perfection of which it is capable without drawing upon the science of ratios and proportions. As examples of crafts guided by ratio and proportion the Brethren listed melodic sounds in music, prosody in poetry, letters in proportioned script, and harmonious colors and proportionally joined figures in painting and mechanical devices. They compared the principles of prosody, "which is the weighing-scale of poetry," to the rules of music, "which can be compared to those of prosody," and likened the proportions governing them to those underlying calligraphy and painting.[15] Just as "the most perfect of productions, the most coordinated of constructions and the most beautiful of compositions" in music and poetry are those "governed by the best of proportions," a script is considered beautiful by them only when its varied letters are proportionally executed in terms of size and order. To produce pleasing images, painters similarly are urged to observe the right proportions of colors, shapes, and sizes for figures.[16]

The Brethren considered visual objects beautiful only insofar as they capture the balanced proportions and symmetries of the universe, which skilled artists take as their ultimate model. They wrote, "In effect, the beautiful in this world is a trace of the universal celestial soul."[17] This recalls Plotinus's argument that the beauty of the material work of art originates from archetypal forms in the artist's mind or soul that imitate spiritual beauty. The Brethren's description of beautiful writing repeats the notion that visual beauty is a harmonious ordering of proportionally related parts:

> We say that all the scripts . . . are founded on two basic principles; which are, the straight line which is identified with the diameter of the circle, and the curved line which is identified with the circumference; all the letters are formed and composed as we have explained in the Epistle on geometry. . . . the best, the most correct and the most beautiful of scripts is that where the characters are of the dimensions governed by the most noble proportion. . . . What we have said on the subject of the proportions of the letters and their reciprocal relationships of length and breadth, is something imposed by the most eminent laws of geometry and the rules of proportion.[18]

We have seen that the proportioned script (*al-khaṭṭ al-mansūb*), based on the module of the circle, was perfected in Buyid Baghdad by Ibn al-Bawwab, who further refined the cursive scripts systematized by Ibn Muqla. The Brethren's lengthy discussion of proportionality in writing, composed after the codification of the proportioned script, was an important source for later writers on the subject, including al-Rawandi in the thirteenth century (see fig. 92), al-Qalqashandi in the fif-

teenth century, and Taşköprizade in the sixteenth century, all of whom explained the same geometric system of proportioning derived from the curved circumference and straight radius of the circle.[19]

That the Brethren's theory of beauty was familiar among Buyid chancellery secretaries and calligraphers is suggested in a treatise on penmanship composed by Abu Hayyan al-Tawhidi (d. after 1009–1010), who knew at least three of the principal members of this fraternity-like group personally. The treatise quotes Euclid as the source of the saying "Handwriting is spiritual geometry which appears by means of a bodily instrument," a saying (often repeated in later sources on Islamic calligraphy) that testifies to the dissemination of Neoplatonic concepts among the court secretaries and scribes. Distinguished as a man of letters, philosopher, and a professional scribe, al-Tawhidi (a protégé of al-Buzjani) wrote his treatise in the same Baghdadi milieu in which congruent geometric patterns with interlocking stars and polygons, based on the modular use of the circle, appear to have been formulated under the guidance of professional mathematicians. The circle was used as a proportioning device in both the proportioned script and in geometric patterning in a cultural context deeply imbued with a mathematical conception of beauty as a harmony between parts and the whole (see fig. 93).[20] The congruence of proportion and symmetry embodied a quantitative notion of beauty based on the fundamental principle of unity in variety. That the aesthetics of proportion, rooted in the musical theories of late antiquity, was also an aspect of contemporary literary criticism is revealed in the philologist and literary theorist al-Jurjani's (d. 1078) description of beauty as a harmonious structural relationship:

> This [beauty] is manifest in all crafts and artistic activities which are associated with subtlety, fineness, and skill. In the images produced in such crafts it is always the case that the more widely different the shape and appearance of their parts are and then the more perfect the harmony achieved between these parts is, the more fascination the images will possess and the more deserving of praise for their skill their creators will be.[21]

As Sabra noted in his introduction to Ibn al-Haytham's optical treatise, the *Kitāb al-manāẓir*, the idea that proportion (*tanāsub*) is the feature most responsible for beauty (frequently encountered in tenth- and eleventh-century Islamic texts) no doubt had a classical origin "though the full history of its transmission and development . . . has yet to be written."[22] Besides proportion the aesthetics of light also played an important role in medieval Islamic descriptions of beauty, among which the one provided in Ibn al-Haytham's optics is the most comprehensive. This remarkable psychological description of visual perception as a subject-object relationship is by far the longest discussion of beauty in Arabic according to Sabra.[23] It can be regarded as a theory of aesthetics relevant for understanding contemporary developments in Islamic visual culture.

Ibn al-Haytham defined beauty (*al-ḥusn*) not as an absolute attribute but as a complex interaction between twenty-two properties (light, color, distance, position, solidity, shape, size, separation, continuity, number, motion, rest, roughness, smoothness, transparency, opacity, shadow, darkness, beauty, ugliness, similarity, and dissimilarity). Only two of these factors, light and color (a quality of light), were by themselves capable of producing beauty, that is, producing "in the soul an effect such that the form appears beautiful." The remaining twenty properties had to be subjectively combined during the process of visual perception.[24] Ibn al-Haytham added to these a third factor capable of causing beauty: "Now beauty may consist in something other than either of the two things we have mentioned, and that is proportionality and harmony (*al-tanāsub wa al-i'tilāf*)."[25] In a fascinating passage he argued that under certain circumstances proportionality alone could produce beauty:

> Proportionality alone may produce beauty, provided that the organs are not in themselves ugly, though not perfect in their beauty. Thus when a form combines the beauty of the shapes of all its parts and the beauty of their magnitudes and

their composition and the proportionality of parts in regard to shape, size, position and all the other properties required by proportionality, and moreover, when the organs are proportionate to the shape and size of the face as a whole—*that* is perfect beauty.

Writing also is not beautiful unless its letters are proportionate in respect of their shapes, magnitudes, positions and order. And the same is true of all visual objects which are combinations of various parts. When, therefore, a survey is made of beautiful forms in all kinds of visible objects, proportionality will be found to produce in them a beauty other than that produced by any one of the particular properties by itself and other than that produced by the conjunction of the particular properties existing together in the form. When the beautiful effects produced by the conjunction of particular properties are examined, the beauty due to that conjunction will be found to be only the result of the proportionality and harmony obtaining between those conjoined properties. . . . Beauty is, therefore, produced by the particular properties, but its completion and perfection is due only to the proportionality and harmony that may obtain between the particular properties.[26]

Ibn al-Haytham elaborated his definition of beauty in calligraphy and visual objects in another passage in which their aesthetic affinity is discussed:

> For the beauty of writing is due only to the soundness of the shapes of letters and their composition among themselves, so that when the composition and order of the letters is not regular and proportionate the writing will not be beautiful. . . . Similarly, many forms of visible objects are felt to be beautiful and appealing only because of the composition and order of their parts among themselves."[27]

Just as "perfect beauty" in writing "comes only from the conjunction of shape and position," abstract patterns, then, can attain aesthetic perfection through their proportional combination of congruent shapes.

Proportion (the geometric order of light) and color (a corporeal quality of light), which according to Ibn al-Haytham belong to the three privileged elements most capable of producing visual beauty, are intimately related to the third element, light. Light is the ultimate source of visual beauty and the precondition of vision since "all visible properties can be perceived only from the forms produced in the eye by the forms of colours and lights of the visible objects." Ibn al-Haytham wrote: "For light produces beauty, and thus the sun, the moon, and the stars look beautiful, without there being in them a cause on account of which their form looks beautiful and appealing other than their radiant light. Therefore, light by itself produces beauty." He added that color, too, can produce beauty by itself, for bright colors "appeal to the beholder and please the eye." When arranged with regard to proportion, the aesthetic value of colorful designs increases considerably since "bright and pure colours and designs are more beautiful when regularly and uniformly ordered than when they have no order."[28]

The sensuous immediacy of the beauty of light and color was no doubt associated with the metaphysics of light and its metaphorical visions of glittering brightness and pure effulgence. In Ibn al-Haytham's theory of vision, the beauty of visual form derives from the diffusion of light and color from visible objects whose rays obey geometric laws embodying harmonious proportions. This aesthetics of light and proportion recalls Plato's reference in the *Philebus* to a timeless beauty of pure geometric forms and colors whose beauty is not relative but absolute.[29]

A notion of aesthetic purity aiming at a transcendental form of abstract beauty seems to be at work in the invention of the *girih* mode, whose geometric shapes occupy an intermediate zone between intelligible and sensible forms. The Brethren of Purity stressed the purifying role of geometry in uplifting the mind to contemplate higher forms of understanding. This aspect of geometry comes out in their reference to Pythagoras, "who heard the music of the spheres after having been cleansed of the defilement of

corporeal appetites and raised to the sublime by constant reflection and by the sciences of arithmetic, geometry, and music."[30] According to the Brethren the final aim of geometry, the gateway to spiritual wisdom, was to permit the soul to "separate itself from this [corporeal] world in order to join, thanks to its celestial ascension, the world of the spirits and eternal life."[31]

Proclus's commentary on Euclid's *Elements,* which according to Ibn al-Nadim had been translated into Arabic by the tenth century,[32] similarly had emphasized the noetic ability of geometry to direct the mind upward to a higher world of supersensible realities. Proclus argued that geometric forms occupy an intermediate position between immaterial higher realities and the confused material objects of the world of senses: "Mathematics occupies a middle position between the intelligible and the sense worlds and exhibits within itself many likenesses of divine things and also many paradigms of physical relations."[33] He described the intermediate status of mathematical forms:

> Mathematical objects, and in general all the objects of the understanding, have an intermediate position. They go beyond the objects of intellect in being divisible, but they surpass sensible things in being devoid of matter. They are inferior to the former in simplicity, yet superior to the latter in precision, reflecting intelligible reality more clearly than do perceptible things. Nevertheless they are only images, imitating in their divided fashion the indivisible and in their multiform fashion the uniform patterns of being. In short, they stand in the vestibule of the primary forms, announcing their unitary and undivided and generative reality, but have not risen above the particularity and compositeness of ideas and the reality that belongs to likenesses. . . . Let this be our understanding, for the intermediate status of mathematical genera and species, as lying between absolutely indivisible realities and the divisible things that come to be in the world of matter.[34]

Stressing the intrinsic beauty of geometric shapes (among which the circle was the most beautiful), Proclus argued that the beauty and order of mathematical discourse "bring us into contact with the intelligible world itself and establish us firmly in the company of things that are always fixed, always resplendent with divine beauty, and ever in the same relationship to one another."[35] He noted that geometry, whose figures are abstract mental projections, "arouses our innate knowledge, awakens our intellect, purges our understanding, brings to light the concepts that belong essentially to us . . . sets us free from the bonds of unreason."[36] This statement recalls that of Ibn Khaldun who, as we have seen, ascribed to geometry the role of enlightening the intellect and purifying the mind like soap, after quoting the saying that allegedly was written on Plato's door: "No one who is not a geometrician may enter our house."[37]

Ibn Sina, who after his education in Bukhara moved between various courts in Central Asia and Iran, including those of Gurganj and Isfahan, defined geometry as a mental abstraction that essentially remained bound to the material world since the mathematical sciences dealt only with accidents. This once again placed geometry in an intermediary position in the quest for metaphysical truth; it was the ladder by which one ascended to astronomical knowledge and from which one then could move up to the metaphysical sciences.[38] This hierarchical ordering of knowledge, commonly encountered in medieval Islamic encyclopedias, was so widely disseminated that it is repeated in Ibn Rashiq's eleventh-century treatise on poetics:

> Knowledge, in the philosophers' opinion, is of three kinds: the highest, which is the knowledge of what escapes sensual perception and can only be attained through reason and analogy; the intermediate, which is the knowledge of the precious rules of decorum that reason derives from natural objects such as numbers, geometry, the art of astrology, and the art of melody; and the inferior, which is the knowledge of particular things and bodily objects."[39]

These notions provided a backdrop for the burgeoning taste for geometric abstraction during the late tenth and early eleventh centuries in a milieu permeated with Neoplatonic philosophy. Even though the spread of the *girih* paralleled the dynamics of the Sunni revival, which rejected the emanationist cosmology with its heterodox implications of "polytheism," light imagery continued to enjoy immense popularity, as we have seen in al-Ghazali's mystical interpretation of the Light Verse. The Sunni atomistic worldview of al-Ashᶜari restored the Koranic concept that the universe was created by God ex nihilo and in time, as opposed to its eternal emanation through an intermediary chain of incorporeal intelligences propagated from a transcendent active intellect or First Cause, like light from the sun. The eternal versus temporal nature of the cosmos also preoccupied the Scholastics in the Latin West, particularly after they were confronted with the twelfth- and thirteenth-century translations of Greek and Arabic sources addressing that subject. Ibn Sina's theory of the creation of forms by emanation, for example, is known to have influenced the philosopher Thomas Aquinas (1225–1274), whose writings were deeply "imbued with Avicennism."[40]

The Sunni orthodox worldview, formulated to vindicate the absolute power of God, subordinated the primacy of human free will and the "light of reason" to the subintellectual categories of intuitive experience, mystical illumination, and love as means of acquiring metaphysical knowledge. Despite this major shift in emphasis, aesthetic concepts originally associated with the doctrine of emanation proved extremely durable. Images of proportion and light continued to live on, modified to reflect the omnipotence of God, the creator of a wonderful universe filled with beautiful signs (*āyāt*) and portents signaling divine wisdom. Al-Ghazali wrote, "Just as the greatness of a poet, writer or artist becomes all the more notable the more you know of the wonderful works of poetry, writing and art; in the same way miracles of the creation of God are a key to the knowledge of the greatness of the Creator."[41]

Although God's nature was bound to remain incomprehensible, the creator had given human subjects, in addition to the miracle of the Koran, the created cosmos through which they may contemplate the divine glory and wisdom. Often accompanied by quotations from the "uncreated" Koran rendered in the proportioned script, geometrized designs abstracted from prototypes provided by nature were therefore potentially imbued with the vision of a divinely created wondrous universe. It is this implicit parallelism between the separate yet analogous realms of nature and art that explains the frequent comparisons between the divine creator and the divinely inspired artist.

Theories of beauty based on an agreeable harmony of proportions and colors instinctively appealing to the human soul or heart are frequently encountered in the writings of post-eleventh-century Muslim authors even though the fascination with Greek philosophy had faded by then. The love of beauty is described in a celebrated passage of al-Ghazali's *Kimyā-i saᶜādat* (Alchemy of happiness), circa 1106, whose relevance for aesthetic theory was noted first by Ettinghausen and recently elaborated by Grabar. Ettinghausen pointed out that this work, which popularized in the Persian vernacular language ideas the same author had developed in a longer Arabic work, the *Iḥyā' ᶜulūm al-dīn* (Revival of the sciences of religion), must have been accessible to the common people, including artisans. Al-Ghazali wrote, "Everything the perception of which gives pleasure and satisfaction is loved by the one who perceives it"; therefore, everything beautiful is an object of love.[42] Concluding that it is God's beauty that leads one to divine love, al-Ghazali described the love of beauty for its own sake, which he differentiated from sensual desire:

> Another cause of love is that one loves something for its own sake. . . . To this category belongs the love of beauty . . . because the perception of beauty is pleasure in itself and is loved for its own sake and not for anything else. Do not believe that love of beautiful forms is conceivable only for the satisfaction of sensual desire. The satisfaction of such a desire is another type of pleasure for which beautiful forms can also be loved. However, the perception of beauty also gives pleasure and can be loved for its own sake alone. . . . The reaction of every healthy constitution

> proves that the contemplation of flowers and birds, of a beautiful colour, graceful design and form gives pleasure. On seeing them even worry and grief leave the human mind, though there is no benefit to be derived beyond the mere looking. These objects give pleasure and everything pleasurable is loved.[43]

In a different passage al-Ghazali emphasized that the highest object of love is God's beauty: "The causes of love (and these include beauty) are real only as applied to God, in all other cases their existence is only delusion, imagination, and metaphorical expression."[44] His discussion of beauty shows how aesthetic concepts elaborated between the ninth and early eleventh centuries by Muslim philosophers, well before Sufism became a dominant trend, were eventually merged into mystical literature. Ibn Khaldun, who like al-Ghazali criticized the philosophers, echoed their Neoplatonic aesthetic notions in a passage describing the perception of beauty by the eye and the ear:

> Agreeable sensations of vision and hearing are caused by harmonious arrangement in the forms and qualities of [the things seen or heard]. This impresses the soul as harmonious and is more agreeable to it.
>
> If an object of vision is harmonious in the forms and lines given to it in accordance with the matter from which it is made, so that the requirements of its particular matter as to perfect harmony and arrangement are not discarded—that being the meaning of beauty and loveliness whenever these terms are used for any object of sensual perception—that [object of vision] is then in harmony with the soul that perceives [it], and the soul thus feels pleasure as the result of perceiving something that is agreeable to it. . . . Thus every man desires beauty in the objects of vision and hearing, as a requirement of his nature.[45]

Ibn Khaldun once again explained the instinctive attraction of the soul to the beauty of harmonious sounds and images as a relationship of love, an emotional attraction caused by the structural affinity between them. The metaphor of love, so often encountered in Islamic sources, appears as late as the sixteenth century in the Ottoman scholar Taşköprizade's encyclopedia of knowledge where, after having described the music of the heavenly spheres he wrote: "Man's soul adores and is in love with beautiful things. Whenever the soul sees a beautiful image or hears a beautiful sound it remembers the realm of intelligible entities and for that reason it is delighted and exalted."[46]

The same psychological theory of aesthetic perception is repeated in the ethical treatise of the Aqqoyunlu thinker al-Dawwani, which was particularly popular in the late Timurid-Turkmen world. This treatise includes a section on harmony and proportion that repeats the Pythagorean notion of the music of the spheres and quotes the inscription about geometry placed over the door of Plato's academy.[47] Again the soul's automatic attraction to beauty is reiterated: "The soul feels an essential affection for any similar proportion, and . . . a pure proportion, wherever observed, is the means of attracting and agitating the spirit: such as beauty, which is a term for correspondence of parts." Al-Dawwani defined audible and visual beauty as a congruence of parts producing a sense of unity: "The effect of cadences, concordant tones, metrical verses, and fine forms, is on account of the eminence of their unity in relation." Since the source of all beauty is no other than God, the soul's attraction to the beautiful can, according to al-Dawwani, provide a foretaste of divine love, a statement echoing al-Ghazali's conception of beauty as that which gives pleasure in itself and yet at the same time is capable of inducing an intuition of higher forms of transcendental beauty.[48] Although their immediate function was aesthetic pleasure, beautiful objects also could lure the receptive viewer to higher levels of metaphysical contemplation about the splendor of the heavens and the mysterious wonders of creation.

Widespread notions about the role of geometry as a bridge between the material and spiritual realms, coupled with the absolute beauty of its harmonious forms capable of purifying the mind like music, must have made geometric abstraction a particularly appealing visual idiom. The purity of a polychromatic abstract design vocabulary dominated by congruent geometric shapes approached

the status of light and color, the only two properties that Ibn al-Haytham singled out as being beautiful in themselves in addition to proportionality. This purity of sterilized forms, absolved from impure defilement, no doubt augmented the positive resonances of geometric and geometrized patterns, often accompanied by Koranic inscriptions. Moreover, the proportionally interlocking colored geometric forms of *girih*s that could trigger an innate aesthetic reaction in viewers must have given medieval designers the hope of endowing their visual creations with the expressive potential and emotional immediacy of music.

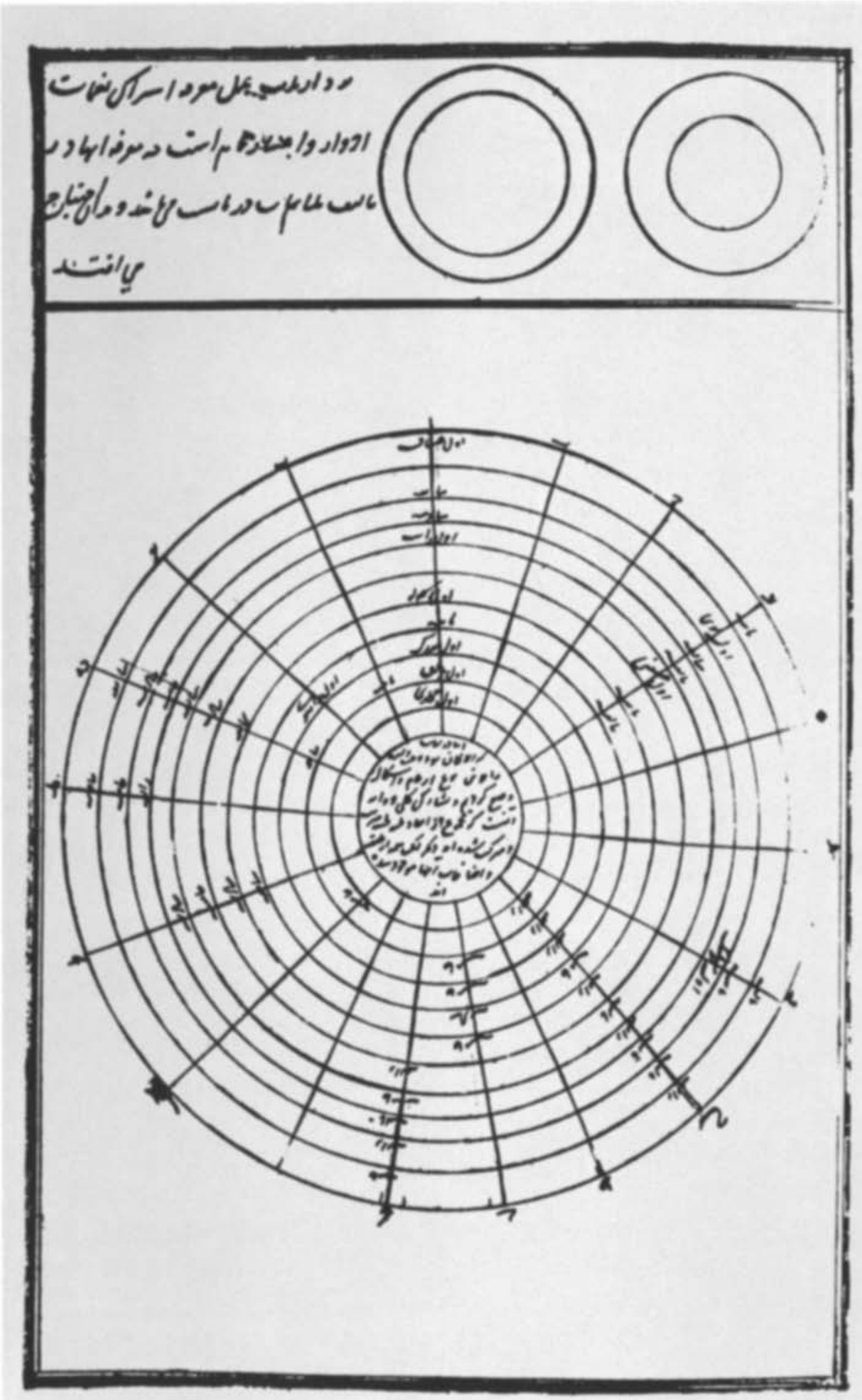
Polychromatic star-and-polygon patterns embodied notions of aesthetic purity and harmony visually aspiring to the music of the spheres. The invisible heavenly orbits of light governing the composition of these patterns can be interpreted as an ambition to raise abstract visual beauty to the same mathematical level as music. Through the use of the circle as a proportioning device, the notion of the music of the spheres found visual expression in *girih* patterns (see figs. 92, 99, 100, 109b, 113b, 121, 122). Just as the consonances of earthly music could strive to echo the heavenly music of the spheres whose transparent bodies emanated light in circular rhythms, so did congruent *girih*s embody a nostalgic yearning for the pure crystalline structure of the heavens, infused with brilliant light. Their heavenly orientation, betrayed by the insistent use of stars, reflected a wider tendency in Islamic art and architecture to emulate celestial prototypes as models, such as the mansions and gardens of paradise or the Bayt al-Maᶜmur (Prosperous house, the heavenly prototype of the Kaᶜba in Mecca).

To conclude, then, the so-called arabesque (whether geometric, vegetal, calligraphic, or figural) can be seen as the offshoot of a classical notion of beauty recast in abstract terms. The aesthetics of proportion and light, most likely inherited from the last remnants of the school of Alexandria, left its enduring stamp on medieval Islamic visual culture. As in medieval Europe and Byzantium, the aesthetic sensibilities of the Muslim world were no doubt permeated with religion, but cultural developments in the mathematical sciences and philosophy had an equally important part to play in shaping visual idioms.

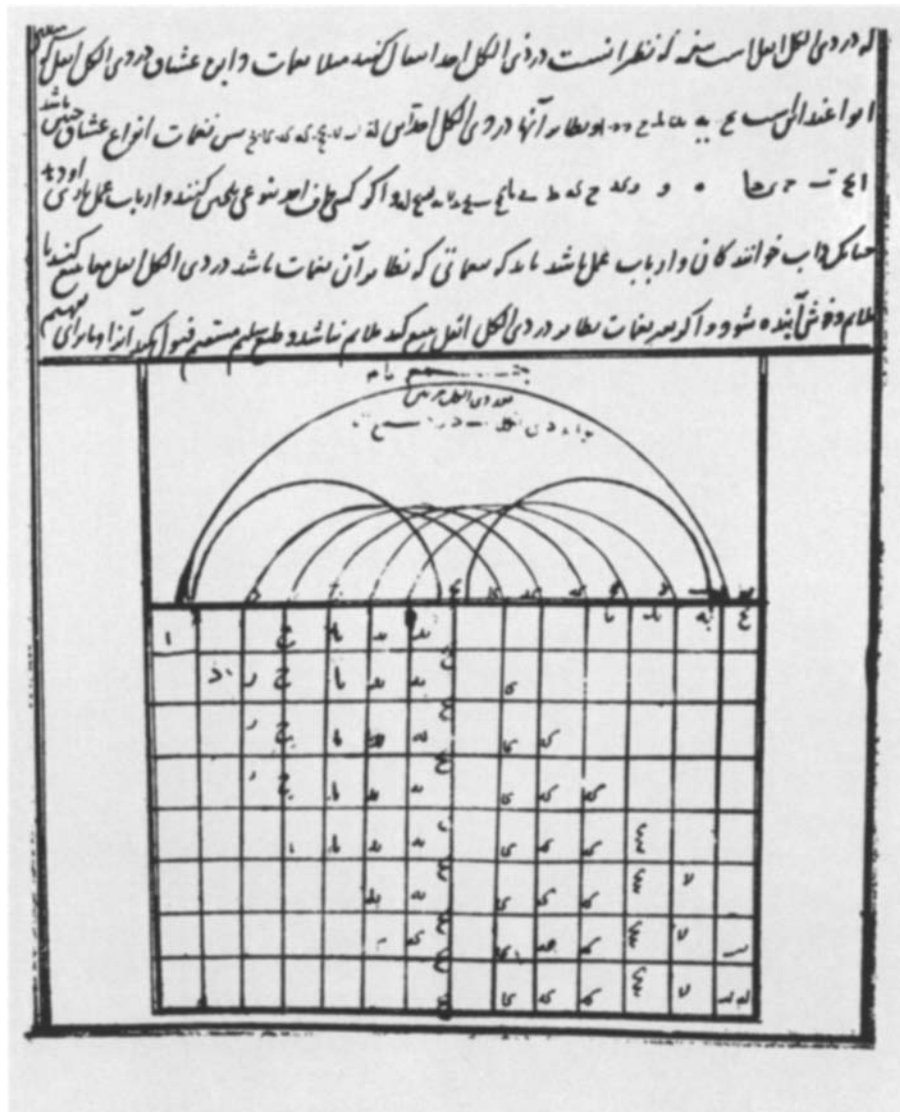
The Latin West and Byzantium had inherited the same late antique aesthetic theories that were assimilated into medieval Islamic culture. The impact of Plotinus's *Enneads* on abstract modes of visual representation in the Byzantine world has been analyzed by André Grabar and others.[49] Such philosophers as Augustine (354–430) and Manlius Boethius (circa 480–524) transmitted the classical concepts of proportion and the love of beauty to the Latin West. Augustine (who had absorbed the classical culture of Carthage before his conversion to Christianity), for example, provided a definition of beauty as that which attracts and pleases through its symmetrical proportions, consonance of parts, and harmony.[50] Like Plotinus, he asked in the *Confessions,* circa 400, "Do we love anything, but the beautiful?" a question prefiguring the equation between love and beauty encountered in many later Islamic texts. Augustine also regarded sight and hearing as the highest senses because they were capable of apprehending measure, beauty, and order, which invite us to contemplate the source of such qualities, that is, God. He did not consider the experience of visual or aural beauty to be merely an end in itself, for he believed that the harmony of beautiful objects occasionally could culminate in the contemplation of divine beauty.[51]

Boethius also linked beauty to a mathematical concept of proportion, reflecting the harmonic structure of the cosmos. According to him ratio and proportion produced beauty in visible and audible forms alike, a beauty capable of arousing aesthetic pleasure in the soul, which is subject to the same laws of proportion that govern the structure of the cosmos.[52] The concept of proportion would assume more complex forms with such writers as Grosseteste, who developed an aesthetics of light and proportion similar to that of Ibn al-Haytham's *Kitāb al-manāẓir.* His new emphasis on light had been foreshadowed by the writings of such philosophers as al-Farabi, Ibn Sina, and al-Ghazali, in addition to Ibn al-Haytham.[53]

With the translation of Arabic philosophical works into Latin, not only classical texts but also the works of Muslim authors became widely available in Europe during the twelfth and thirteenth centuries, resulting in an intricate mesh of intertextuality. After that point it becomes difficult to trace the strands of influence in medieval



121. ᶜAbd al-Qadir b. Ghaybi al-Hafiz al-Maraghi (d. 1435), folio with circular diagrams. From his *Maqāṣid al-alḥān* (Purports of music), a treatise on musical theory, written around 1421–1423 in the Timurid court at Samarqand and dedicated to Sultan Murad II, copied at the Ottoman court in 1437–1438, red and black ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS R. 1726, fol. 42v.



122. ᶜAbd al-Qadir b. Ghaybi al-Hafiz al-Maraghi (d. 1435), folio with geometric diagram. From his *Maqāṣid al-alḥān* (Purports of music), a treatise on musical theory, written around 1421–1423 in the Timurid court at Samarqand and dedicated to Sultan Murad II, copied at the Ottoman court in 1437–1438, red and black ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS R. 1726, fol. 43r.

European aesthetic theories, which exhibit a remarkable similarity to their Islamic counterparts. The Scholastic philosophers of Europe were nourished by the new translations of Greco-Arabic texts to such a degree that it is impossible to tell what their writings might otherwise have been like. Not surprisingly Aquinas's often-quoted passages on beauty in the *Summa Theologica,* 1266–1273, exhibit a striking affinity to aesthetic concepts encountered in medieval Islamic texts, particularly in the writings of Ibn Sina, which he is known to have consulted. After all, the attempts of Muslim philosophers to reconcile pagan Greek philosophy with Islamic monotheism corresponded so closely with the aims of the European Scholastics that it is easy to understand why the latter were readily drawn to Arabic modifications of Greek originals. Aquinas's psychological definition of beauty emphasized "proper proportion or consonance" and "brightness," aesthetic categories not so different from their Islamic counterparts and suggestive of an abstract linear style with glowing colors.[54]

The uplifting emotional force of visual beauty, as described by Abbot Suger (1081–1151) with reference to his new choir at Saint-Denis, would not have been foreign in a contemporary Islamic context. In this famous description religious and aesthetic elements are inextricably fused:

> Thus, when—out of my delight in the beauty of the house of God—the loveliness of the many-coloured gems has called me away from external cares, and worthy meditation has induced me to reflect, transferring that which is material to that which is immaterial, on the diversity of the sacred virtues: then it seems to me that I see myself dwelling, as it were, in some strange region of the universe which neither exists entirely in the slime of the earth nor entirely in the purity of Heaven; and that, by the grace of God, I can be transported from this inferior to that higher world in an anagogical manner.[55]

Suger was describing neither a simple pleasure in the sensuous nor an intellectual contemplation of the supernatural; the intuitive passage from aesthetic pleasure to mystical joy was virtually instantaneous. As Umberto Eco wrote, medieval taste "involved an apprehension of all the relations, imaginative and supernatural, subsisting between the contemplated object and a cosmos which opened on to the transcendent."[56] In the integrated medieval mentality metaphysical aesthetic concepts mingled constantly with daily artistic judgments, a process facilitated by the analogical mentality of an age that equated macrocosm with microcosm. The notion of a hierarchically ordered universe where the pattern of the whole was echoed in the pattern of the parts made drawing inferences from one category of parallel phenomena to the other all the more easy. According to Eco, medieval discussions of transcendental beauty therefore allowed, "both for the autonomy of aesthetic value and for its place within a unitary scheme of values—or, to put it in medieval terms, within a unitary vision of the transcendental aspects of being."[57]

The notion of transcendental beauty was a common denominator of medieval aesthetics in both the Christian and Islamic worlds alike. The theocentric ethos of these worlds revolved around a shared preoccupation with grasping the nature of the relationship between a transcendent God and a created world, and between the celestial and terrestrial realms. In the Islamic world beautiful visual objects that were capable of arousing love could evoke a foretaste of metaphysical beauty, but their abstract forms lent themselves to a wider variety of subjective interpretations than their figural counterparts in Christendom. They could resonate with suggestive allusions and correspondences to the higher order of things, but at the same time their polysemy allowed for a relatively open-ended series of emotional responses from audiences.

No doubt the similarities of medieval aesthetic theories in the Islamic and Christian contexts were conditioned by a shared classical heritage. Similar aesthetic theories resulted in differentiated visual idioms in the Latin West, Byzantium, and in the Islamic lands, yet these idioms were united by a transcendental ethos expressed through the predominant use of abstract geometric schemes and bright colors. Despite striking stylistic differences an underlying similarity remained, unified by a medieval orientation toward metaphysical splendor and the wonderful marvels of creation.

CHAPTER 11. GEOMETRIC ABSTRACTION AND THE PSYCHOLOGY OF VISUAL PERCEPTION

The medieval Islamic theory of the soul's attraction to harmoniously proportioned and brightly colored visual forms involved not only an objective conception of ideal beauty but also the subjective, psychological processes of aesthetic perception. It presupposed a subject-object relationship that took into account the emotional responses of the viewer. The unprecedented emphasis of late antique philosophers on artistic creativity and the artist's imagination (*fantasia*) was perpetuated by medieval Muslim philosophers. Modifying Plato's views to accord a higher status to art, Plotinus's *Enneads* had stressed the creative imagination of the artist who went beyond just holding a mirror to nature by shaping raw material on the basis of ideal mental images. According to Plotinus the beauty of the material work of art originated from such archetypal forms abstracted in the artist's mind or soul from the suprasensible intelligible world; hence the *Enneads* assigned a revelatory function to art that could transcend mere sense perception. This late antique conceptualization of artistic creativity as a profoundly intellectual activity was also elaborated by Boethius.[58]

The inner faculty of *fantasia* (*mutakhayyila*), which makes spiders weave their webs and bees produce their honeycombs, was not only responsible for artistic creation but also for dreams and prophetic visions. The status of prophecy would particularly preoccupy thinkers in the Islamic world, given the prophet Muhammad's purely human nature, so different from that of Christ, the son of God. The intimate relationship between prophecy, dreams, and the artistic imagination explains why creativity is often attributed in Islamic texts to dream inspirations. The Arab singer-composer Maʿbad (d. 743), for example, is said to have learned his vocation in sleep, just as the renowned Umayyad singer al-Gharid (d. circa 716–717) heard mysterious voices in dreams on the basis of which he composed songs.[59]

Texts frequently refer to artistic creation as a form of divine inspiration. Al-Tawhidi's treatise on penmanship, for example, compares the inspired creativity of the celebrated calligrapher Ibn Muqla to that of the bee. Citing the Koranic verse on the bee as a wonder of creation (16: 68), al-Tawhidi described this calligrapher: "He is a prophet in the field of handwriting; it was poured upon his hand, even as it was revealed to the bees to make their honey cells hexagonal."[60] Along the same lines, the autobiography that the architect Sinan dictated to Saʿi exalts his mastery in architecture as a form of saintliness (*velāyet*) comparable to the wisdom of the sage Loqman (*ḥikmet-i Loḳmān*). Sinan attributed his masterpieces to his natural "talent [*ḳābiliyyet*] which is a grace granted by God," cultivated by his own diligent efforts in perfecting his art (*ṣanʿat*). The mental or spiritual origin of artistic creation, which could at times attain the level of a saintly miracle, explains the frequent praise of skilled workmanship in Islamic texts and the pride of craftsmen in their own works.[61]

Ingenious talent, culminating in the prophetic vision, was regarded in the post-Hellenistic philosophical tradition that Islam inherited as an intuitive inner faculty of the skillful artisan. Unlike

animals, who only followed natural instincts, human beings were capable of a higher order of creativity that is often linked in Islamic thought with the realm of the internal senses, a group of cognitive faculties located in the brain and separate from the external senses. Ibn Sina, for example, argued that although animals transformed matter by building nests, theirs was a spontaneous activity when compared to the creation of an artificial environment by mankind through work and creative invention. Differentiating the "sensitive imagination" of animals from the "rational imagination" of humans, he attributed a special spiritual capacity to the latter that is cultivated in the arts, sciences, and noble actions. Ibn Sina singled out the arts and language as the two faculties that distinguish humans from animals, a distinction also made by the Brethren of Purity and Ibn Khaldun.[62]

The participation of internal senses such as imagination, cogitation, and memory in the processes of artistic creation and aesthetic perception endowed these activities with an intellectual dimension. The important place given in Muslim thought to the internal senses, which Aristotle's *De Anima* and *De Memoria et Reminiscentia* had briefly touched upon, has been demonstrated in a study by Harry Austryn Wolfson that traces their history and varying classifications.[63] Their relevance for the arts has been noted by Muhsin S. Mahdi:

> The structure of the soul and the activities of its various parts or powers and their relationship and hierarchy are of interest to any artist whose art consists of creating a work that pleases or conveys a message or arouses a certain feeling in the human beings who look at it or work or worship in it. Sense perception, imagination, intellect, passion, and practical understanding are all parts of the soul that the architect addresses to some extent through what he creates. The power of imagination, its functions in dreaming, the way it mediates between understanding and sense perception, its role as a receptacle of individual perception or revelation, and its creative role in representing this perception or revelation in sensible forms are all questions crucial to any discussion of . . . art works.[64]

Summers also emphasized the intimate link between visual aesthetics and the internal senses that performed judgments of distinction, comparison, association, and combination. He argued that the growing status of the internal senses in medieval Europe around the late twelfth and early thirteenth centuries helped rescue the mechanical arts (previously linked to the external senses) from the pejorative associations they had acquired by the ninth century, a transformation that contributed to the rising social position of their practitioners. Wolfson pointed out that it was Latin translations of Greek and Arabic sources that inspired this new interest in the internal senses; he noted that Ibn Sina's writings on that subject were drawn upon extensively by thinkers including Aquinas, Bacon, and the philosopher-scientist Albertus Magnus (circa 1200–1280). Aquinas's psychological doctrine of art, which underlined the role of the internal senses in artistic creation and aesthetic perception, is, therefore, closely related to Islamic aesthetic theories.[65] Summers stated that the internal senses answered an obvious need: "They were 'faculties' responsible for all those necessary activities of the soul that were at once higher than sensation, lower than the intellect, and uniquely human . . . in the discussion of the internal senses is to be found the premodern treatment of the 'unconscious' processes of association and recollection, of ingenuity and even genius."[66]

The internal senses, then, acted as intermediaries between the external senses and the intellect. Sensations conveyed to the mind by the eye and ear, commonly regarded as the highest of the external senses, were filtered through the prism of the internal senses constituting a locus of aesthetic sensibility. The internal senses not only conferred a prestigious mental status to artistic creation but also assured the power of artifacts to generate emotional responses in their audiences. Unlike early medieval Europe where the late antique link between the internal senses and the arts and crafts was largely severed, the Muslim world perpetuated that link with no break, assigning a respectable position to the mechanical arts, which were firmly situated among the expressions of the creative human soul. This view was eloquently expressed

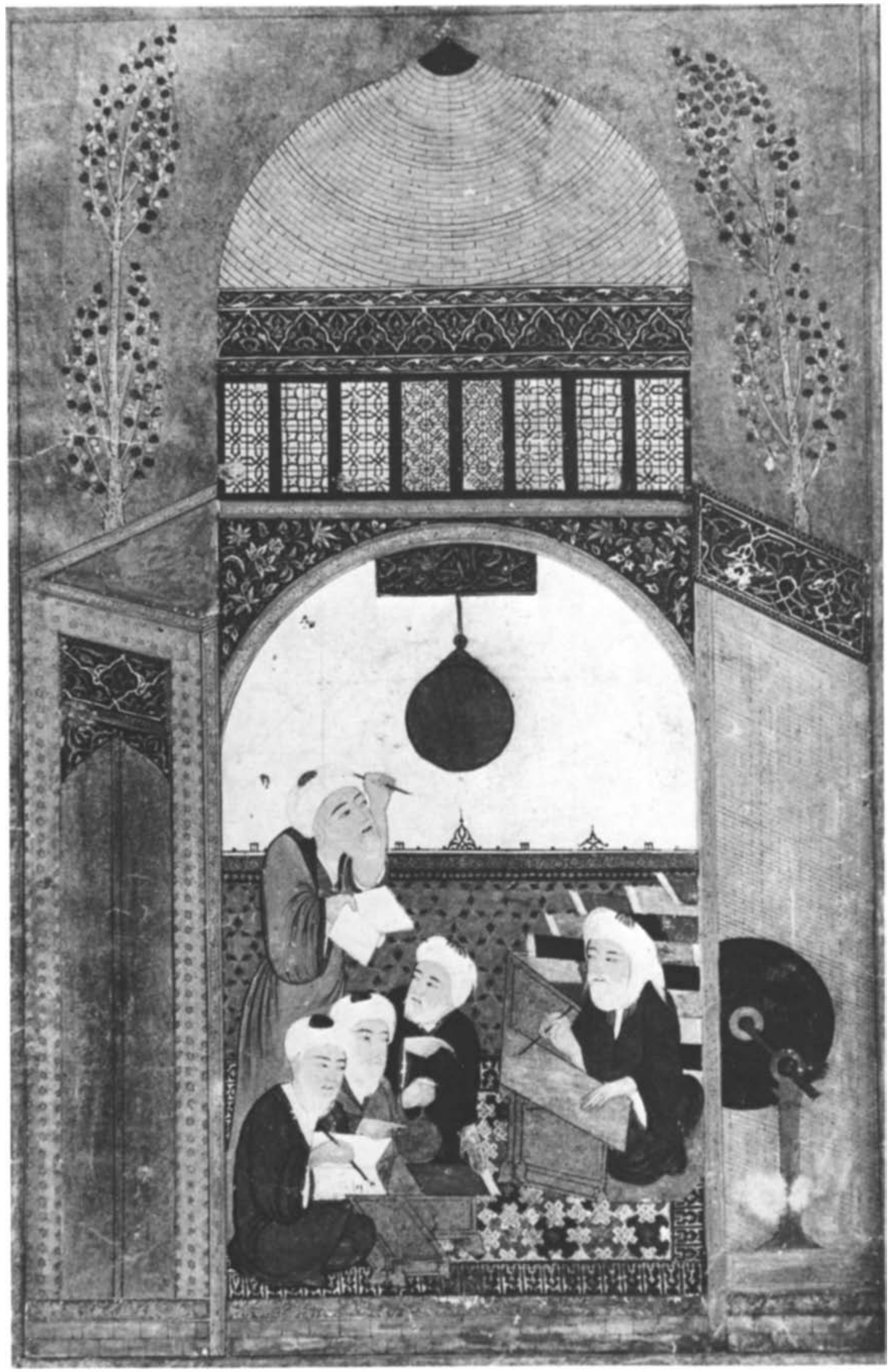
by Ibn Khaldun, who regarded the arts and crafts as "the result of man's ability to think, through which he is distinguished from animals." Combining theory with praxis, the crafts, which transcended mere manual labor, were distinctive signs of human civilization: "The [susceptibility] of the crafts to refinement and the quality of [the purposes] they are to serve in the demands made by luxury and wealth, then, correspond to the civilization of a given country."[67] These statements of Ibn Khaldun were rooted in views developed by Islamic philosophers between the ninth and early eleventh centuries, views that trickled down into popular mystical texts, literature, and biographical works on calligraphers and painters.

Al-Kindi and al-Farabi were among the earliest Islamic philosophers to have discussed the internal faculties of the soul. Al-Farabi, whose definition remained close to that of Aristotle, enumerated five faculties: imagination, estimation, memory, compositive human imagination, and compositive animal imagination. This list was modified in the epistles of the Brethren of Purity where the five internal (spiritual) senses symmetrically counterbalance the five external (corporeal) senses and act as the servants of their king, the soul. In addition to the first three internal senses cited by al-Farabi, the Brethren listed the "faculty of speech" and the "productive faculty (*al-quwwa al-ṣāniʿa*), the seat of which is in the hands and fingers and by means of which the soul produces the art of writing as well as the other arts." The inclusion of the productive faculty among the internal senses implied that the manual crafts carried the imprints of their creator's minds. They transcended mere sensual experience since they involved the inner, mental activities of the human soul.[68]

The relatively high status accorded to the arts and crafts is also apparent in the Brethren's epistle on the "loftiness of the crafts" (*sharaf al-ṣanā'iʿ*). This epistle once again reflects the intellectual basis of the crafts, intimately linked with the "productive faculty" of the soul. Here the crafts are defined as the imprints on raw matter of mental images (*al-ṣūra*) formed in the minds of their creators, and several crafts are identified as lofty with respect to particular criteria. For example, fireworks, painting, and music are singled out as being lofty in terms of their connection to the soul. The latter two are described as products of ideal forms distilled in the souls of painters and musicians whose artistic beauty is capable of moving the soul and triggering a sense of pleasure and wonder (*al-taʿajjub*).[69]

Ibn Sina also linked the internal senses of imagination (capable of abstracting matter) and estimation (capable of a more elevated form of abstraction going beyond material accidents) with artistic activity. He argued that these faculties were essential "to deduce plans concerning transitory things and to deduce human arts."[70] In his various writings on the internal senses, which elaborated and refined those of his predecessors, Ibn Sina listed seven categories that augmented al-Farabi's five. His two additional faculties, the "common sense" (that which centrally coordinates the internal senses) and "recollection" (that which restores forgotten things to memory) sometimes were combined with the others in a five-fold classification.[71] The abstractive powers of the rational soul were described by Ibn Sina in terms of their subservience to reason in a hierarchical scale rising in degrees from the lowest sensuous faculties (vegetative and animal) to the highest rational ones. His theory of the soul recognized that some individuals were gifted with an inborn intuitive power or insight called "holy reason" (or holy faculty), reserved as a divine favor for the very few. Unlike al-Farabi, who had ascribed prophecy to an exceptional perfection of the imaginative faculty, Ibn Sina assigned it to insight or holy reason, described as the highest of the human faculties.[72]

Al-Ghazali, too, attributed prophecy and sainthood to the highest degree of insight, the "prophetic holy spirit" that operates where "the intellectual and cogitative spirit falls short." Unlike Ibn Sina, who envisaged the conjunction of insight with divine revelation as an intellectual experience, al-Ghazali regarded it as a mystical one. For him the heart (comprising the spirit and rational soul) was the secret of divine knowledge rather than the brain, but at the same time he awarded the intellect "an unambiguous cachet of legitimacy."[73] Consequently al-Ghazali recognized the five internal senses, assimilating them in a less systematic manner into his various writings in which the heart and mystical love play an important role. He sometimes wrote about a sixth sense (referred to variously as the soul, the spirit, or the



123. Nasir al-Din al-Tusi and his colleagues at the Maragha observatory, miniature painting. From a scientific anthology, Shiraz, ca. 1410. Istanbul, İstanbul Üniversitesi Kütüphanesi, MS F. 1418, fol. 1v.

heart) that intuitively perceived the beauty of the inner world, far more perfect than that of the outer world: "The beauty of the outer form which is seen with the bodily eye, can be experienced even by children and animals . . . while the beauty of the inner form can be perceived by the eye of the 'heart' and the light of inner vision of man alone."[74] The popular mystical distinction between inner (*bāṭin*) and outer (*ẓāhir*) vision is repeated in another passage by al-Ghazali:

> The inner vision is stronger than the outer one, the "heart" keener in perception than the eye and the beauty of the objects perceived with the "reason" is greater than the beauty of the outer forms which present themselves to the eye. Hence the pleasure of the "heart" over the exalted divine objects which it sees and which are too lofty to be perceived by the senses must necessarily be more perfect and greater, and the inclination of sound disposition and reason toward them must be stronger. . . . He who lacks the inner vision cannot perceive the inner form and cannot derive pleasure from it, love it and incline toward it.[75]

The role of the artist's internal faculties in creating beautiful objects capable of arousing pleasurable awe was acknowledged by al-Ghazali: "The beautiful work of an author, the beautiful poem of a poet, the beautiful painting of a painter or the building of an architect reveal also the inner beauty of these men."[76] However, nowhere in his writings, which often use craft analogies, does one find any reference to artifacts as symbolic representations of religious or mystical doctrines. Like earlier writers, he recognized the capacity of beautiful objects to reflect creative skill and to move the soul with love, but the rest was left up to the subjective inclinations of each viewer.

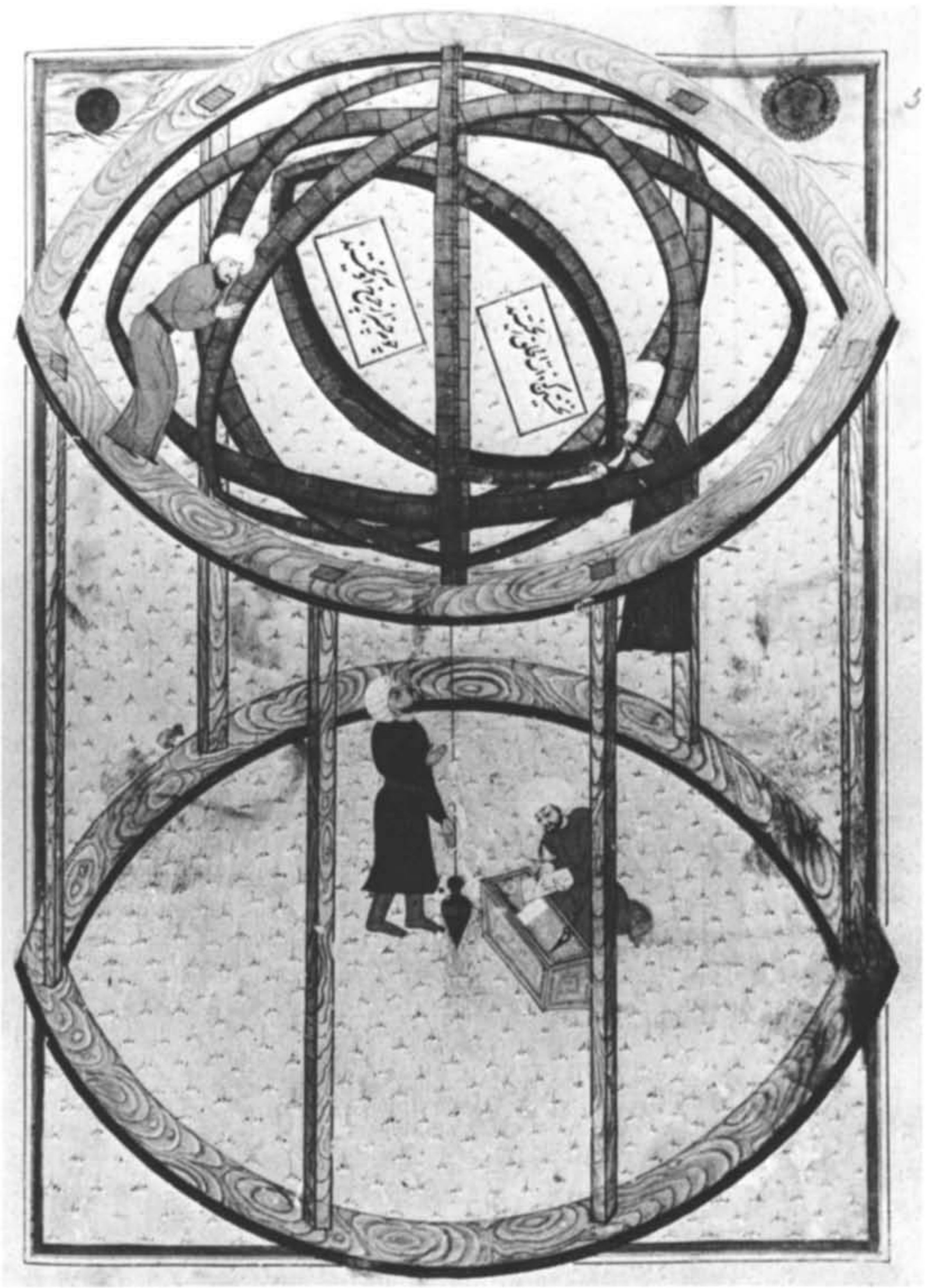
Philosophical theories about the internal senses, which eventually were incorporated into popular mystical literature, also penetrated more specialized texts on poetics, music, calligraphy, and optics. In that respect Ibn al-Haytham's *Kitāb al-manāẓir* is particularly significant since its author also wrote a treatise on architecture. This optical treatise, so influential in Europe after the thirteenth century, became available in Iran through an expanded translation and commentary, the *Tanqīḥ al-manāẓir* (Revision of the *Optics*), circa 1300, of Kamal al-Din al-Farisi, who had studied with Qutb al-Din al-Shirazi at the Maragha observatory (fig. 123). This insightful work became the main vehicle for disseminating Ibn al-Haytham's optical theories in the post-Mongol Islamic world. The *Tanqīḥ* was abridged with a new commentary for Murad III by the sixteenth-century Ottoman astronomer-engineer Taqi al-Din b. Maᶜruf who was attached to the royal observatory in Istanbul, modeled on earlier Ilkhanid-Timurid observatories in Maragha, Tabriz, and Samarqand (fig. 124).[77]

Ibn al-Haytham's *Kitāb al-manāẓir* shows that aesthetic judgments were considered embedded in the subjective processes of the psychology of visual perception, which invariably involved the internal senses. Here beauty is defined not as an absolute attribute but as a contextual subject-object relationship involving inner mental operations of cognition that did not take place in a cultural void. The internal senses of imagination (performing judgments of common sense), recognition, remembrance (memory), and inference worked together through the mediation of the external sense of sight in the subjective process of aesthetic judgment. Ibn al-Haytham wrote:

> Not everything perceived by the sense of sight is perceived by pure sensation; rather, many visible properties are perceived by judgment and inference in addition to sensing the visible object's form, and not by pure sensation alone.
>
> Now sight does not possess the capacity to judge; rather it is the faculty of judgment that discriminates those properties. But the discrimination performed by the faculty of judgment cannot take place without the mediation of the sense of sight.[78]

As we have seen, the perception of beauty involved, according to Ibn al-Haytham, a complex interaction between twenty-two visual properties capable of producing beauty either individually or in combination with one another. Perfect beauty

124a, b. Taqi al-Din b. Maʿruf and his colleagues at the Istanbul observatory, miniature painting. From Lokman, *Shahanshāhnāma* (Book of the king of kings), Istanbul, ca. 1581–1582. Istanbul, İstanbul Üniversitesi Kütüphanesi, MS F. 1414, fols. 56v–57r.



came about through the proportionality and harmony among particular properties, only two of which, light and color, were perceived by "pure sensation." The rest required the involvement of the internal senses:

> The sense of sight perceives the forms of visible objects from the forms that come to it from the colours and lights of those objects. And its perception of lights *qua* lights and of colours *qua* colours *is* by pure sensation. But those properties in the form which, or the like of which, it has previously perceived, and which, or the like of which, it remembers having perceived, are at once perceived by recognition from the signs in the form. The faculty of judgment then discerns this form, thus perceiving from it all properties in it, such as order, outline, similarity, dissimilarity, and all properties in the form the perception of which is not affected by mere sensation or by recognition. Therefore, among the properties that are perceptible by the sense of sight, some are perceived by pure sensation, others by recognition, and others still by a judgment and inference that exceeds the inferences of recognition.[79]

Ibn al-Haytham thus differentiated "pure sensation" from inferential "perception." He further subdivided perception into "glancing perception," which is an almost instantaneous recognition of repeatedly seen familiar forms firmly embedded in visual memory, and "contemplative perception," a longer operation involving the inspection of all parts of an unfamiliar or complex object. The choice between contemplating or glancing is left to the viewer:

> Having shown this, we [now] say that sight perceives visible objects in two ways: by glancing and by contemplation. For as soon as sight takes notice of the object, it perceives its manifest features. Then it may or may not subsequently contemplate the object. If it contemplates and inspects all its parts, then it will ascertain its form. If it does not contemplate the object and scrutinize all its parts, then it will perceive a non-ascertained form of it. . . . When, however, sight perceives an object and contemplates it, it perceives a verified form of it; and it perceives this form by contemplation.[80]

As examples of immediate recognition through glancing, Ibn al-Haytham cited familiar written words (such as *Allāh*) that have appeared so many times before the eye of a literate person that they are perceived "by recognition at the moment of glancing," without the need to inspect the letters one by one. He also mentioned a wall "covered with designs and decorations" that after being contemplated for the first time becomes so familiar that the next time it is seen the "sight will perceive its form by recognition."[81] Visually complicated forms requiring the concentrated contemplation of the gaze, as opposed to the fleeting glance, include "minute designs, letters of a script, tattoo marks, wrinkles and the difference between closely similar colours" whose "fine features appear only after they have been scrutinized and contemplated."[82] The reference to minute designs and calligraphy recalls Ibn al-Haytham's earlier remarks on proportioned scripts and harmoniously composed designs, which according to the following statement can be fully appreciated only by contemplative vision:

> When sight perceives an object whose beauty consists in the conjunction of properties and in their proportionality, and it contemplates the object thus distinguishing and perceiving the properties that produce beauty by being conjoined or by being proportionate to one another, and this perception occurs in the sentient, and the faculty of judgment compares those properties with one another, then that faculty will perceive the beauty of the object that consists in the conjunction of the harmoniously combined properties in it.[83]

Although Ibn al-Haytham stated this as a general axiom, its implications for the aesthetic perception of *girih* patterns and proportioned calligraphy are obvious. It is not unlikely that the

Iraqi mathematician had become acquainted with these two complementary modes of design before he moved to the Fatimid court in Cairo to regulate the flow of the Nile. He may have been thinking about them while writing his treatise, which often uses concrete examples familiar to him including a striking reference in the chapter on errors of vision to shadow plays (known to have existed in Fatimid Egypt).[84] Even if Ibn al-Haytham did not base his statements on proportioned scripts and geometric patterns, they still provide valuable insights about contemporary aesthetic judgments.

One implication is that artifacts may have been designed to take into account the processes of visual perception outlined in Ibn al-Haytham's psychological optics (or in other optical texts), particularly since aesthetic theories so consistently emphasize the emotional responses beautiful artifacts induced in their viewers. This was the case in the royal halls of the Alhambra, where poetic inscriptions invite the viewer to examine attentively their visual beauty, which exceeded the most extravagant conceptions of the imagination (*khayāl* or *khiyāl*). For instance, one of the poems in the Hall of Two Sisters reads, "I am the garden appearing every morning with adorned beauty; contemplate my beauty and you will be penetrated with understanding." A different inscription in the same hall refers to the unfolding of so many wonders that "the eyes [of the spectator] remain forever fixed on them, provided he be gifted with a mind [to estimate them]," a statement alluding to the intellectual nature of aesthetic perception.[85]

Another implication of Ibn al-Haytham's psychological theory of optics is that the willful complication of vision by intricately decorated surfaces was a calculated way of inducing contemplative vision, a "way of seeing," which often is referred to as the "scrutinizing gaze" (*imᶜān-i naẓar*) in Ottoman texts.[86] Elaborately patterned surfaces, covered by multilayered geometric designs interlaced with geometrized vegetal, calligraphic, and occasionally figural motifs, constituted magnetic fields designed to attract the gaze with their bewildering vertiginous effects. Their infinitely extendable, nondirectional patterns of line and color, with no single focal point or hierarchical progression toward a decorative climax, required the insertion of subjectivity into the optical field; they presupposed a private way of looking. Such surfaces seduced the eye to alight on harmoniously combined colors and abstract patterns that could stir up the imagination, arouse the emotions, and create moods. Instantly recognizable pious aphorisms and familiar names, accompanied by longer quotations from the Koran, the hadith, or poetry that addressed literate audiences, further enriched the intellectual potential of visual perception. Visually complicated architectural revetments, open to a wealth of resonances and a multiplicity of meanings, interacted in different ways with the subjectivity of viewers. They created artificial environments of fantasy and contemplative introspection, simultaneously reflecting the glory of the builder, the decorator, the patron, and of God, in addition to advertising their own sheer visual richness.

Written sources comment not only on the internalized mental processes of visual perception but also on the ingenious skill of architects and decorators who ennoble raw matter through ideal mental forms abstracted by the power of the internal senses. The late tenth-century Baghdadi philosopher al-Sijistani described the musician's creativity as emanating from the soul and intellect, recalling the Brethren of Purity's characterization of painting and music as bearers of mental abstractions formed in the souls of their creators through a distillation of sense perceptions from the natural world. Al-Sijistani was quoted by his friend al-Tawhidi:

> Music advenes to the soul and is present therein in a subtle and noble manner. And if the musician happens to have a receptive nature, responsive matter, suitable disposition, and a pliant instrument, he pours out over it, with the aid of the intellect and soul, an elegant cast and wonderful harmony, giving it a beloved form and remarkable embellishment. His faculty herein is by means of communication with the rational soul. Nature consequently needs art because it attains its perfection through the rational soul by means of skillful art.[87]

The role of the imagination in magically transforming the raw material of art by endowing it

with a nobler intellectual quality is compared to the power of alchemy by al-Jurjani:

> Poetry creates out of ignoble material inventions of transcendental value; and acts in such a manner as to make you believe that alchemy is truthfully capable of performing what is claimed for it, and that the philosopher's stone is true and credible—save that these operations are in the case of poetry operations which involve man's imagination and understanding rather than the body or senses.[88]

Al-Jurjani added that the admiration and delight aroused by this type of imaginative creation is essentially the same whether expressed in words or visual forms. As Priscilla P. Soucek has shown, the mental origin of images, painted from memory and from forms stored in the imagination, is consistently stressed by Nizami.[89] His references to painters and painting reveal that philosophical theories connecting the internal senses with the arts had filtered down into poetry and craft traditions. The artistic imagination is frequently praised in Timurid-Turkmen sources. Khwandamir, for example, described a glass vessel with representations of thirty-two different artisans made by Khwaja ᶜAli Arizagar in 1465 as "such a configuration that no more beautiful picture could be reflected in the mirror of the imagination." The same source refers to the Timurid painter-decorator Mawlana Hajji Muhammad Naqqash, attached to Sultan Husayn Bayqara's court at Herat, who was an expert in the art of depiction and illumination: "He constantly painted strange things and wonderful forms on the pages of time with the brush of imagination." Such passages also are encountered in the sources of the Mughals who directly inherited the Timurid tradition, like the eulogy of Ahmad Lahori as a "Wonder of the Age" who "used his chisel to remove rust from the face of Imagination." Evliya Çelebi referred to *girih* patterns intricately interlaced with vegetal motifs in similar terms, as designs that are "pleasing to the imagination" (*khayāl pesendīde*).[90]

The enduring impact of psychological theories of aesthetic perception becomes apparent in Mir Sayyid-Ahmad's preface to a Safavid album of paintings and calligraphy known as the Amir Ghayb Beg Album (1564–1565). This is one of the sources that cites the *girih* among the seven modes of abstract design used by illuminators (*naqqāsh*) who very often were skilled in narrative miniature painting and in calligraphy as well. Asserting that "art is known as the key to wisdom," the author praised painters who abstract sense perceptions in their imaginations:

> It is no secret that the amazing images and wonderful motifs of the practitioners of this craft are well known in every region and are the object of contemplation for those possessed of insight. The imaginative power and elegance of nature that this group has, no one of the other arts possesses. The beauty that unveils her face in the tablet of the painter's mind is not reflected in everyone's imagination.[91]

The *Qānūn al-ṣuwar* by Sadiqi Bek, another Safavid source that discusses the seven codified modes of illumination and calligraphy, similarly emphasizes the creative imagination (*khayāl* or *khiyāl*).[92] This text, couched in the metaphysical vocabulary of mysticism and filled with praises of the Shiᶜi imam ᶜAli, highlights the dichotomy between the inner and outer meanings of forms that only an artist with "natural talent" can penetrate after having received full training from a "saintly" master. In a rare passage the author described the intensely emotional character of his artistic activity that was prompted by an inner voice: "Your true vocation is art (*kasb-o hunar*), seek it diligently the rest of your days. Pursue it militantly, and cling to it mightily; for life without art (*hunar*) is bleak." This voice completely possessed him:

> My heart was now moved solely by thoughts of pure bliss, and the pursuit of my true vocation—art—became increasingly impassioned. . . . I clung to but one profound hope: to be inspired by a touch of the Bihzad. And then, bare of all illusory passions, I could paint the bazaar-world of pictured things with the sole idea of drawing near to their real nature.[93]

Once again, the implication is that through piercing inner vision the artist is able to transcend mere outer appearances and penetrate their essence. Sadiqi Bek was careful to distinguish the narrative figural painting of the miniaturist from the seven fundamental modes of abstract design employed by the illuminator. He pointed out that while the former genre of painting must be nourished by the direct observation of nature, in the latter the "shifting values of observation are not a desideratum." Like calligraphy, abstract illumination had to creatively modify models codified in the past through artful imitation (*tatabbu*ᶜ, a mode of poetic imitation or emulation in which the poet seeks to exhibit originality by imaginatively reworking earlier models).[94]

This analogy with imitational poetry is revealing because it highlights the intertextuality and convention-bound graphic autonomy of abstract modes of design to which the *girih* belongs. It circumscribes creativity in the *girih* mode within a comparative, intertextual framework in which originality is measured with respect to previously codified models renewed in an ever-widening canon of interlinked forms. Once internalized through an initial period of workshop training, the geometric repertory disseminated by *girih* scrolls allowed designers to demonstrate their skill within preestablished structural molds that provided a wide margin for improvisation. The use of such conventional structural molds by poets is described in Shams-i Qays's early thirteenth-century Persian manual of prosody:

> The necessary components of poetry are correct words, palatable terms, eloquent expressions, and subtle thoughts, which, when poured into the mold of agreeable (*maqbūl*) measures, and drawn out into a string (*silk*) of pleasant bayts, is called good poetry.[95]

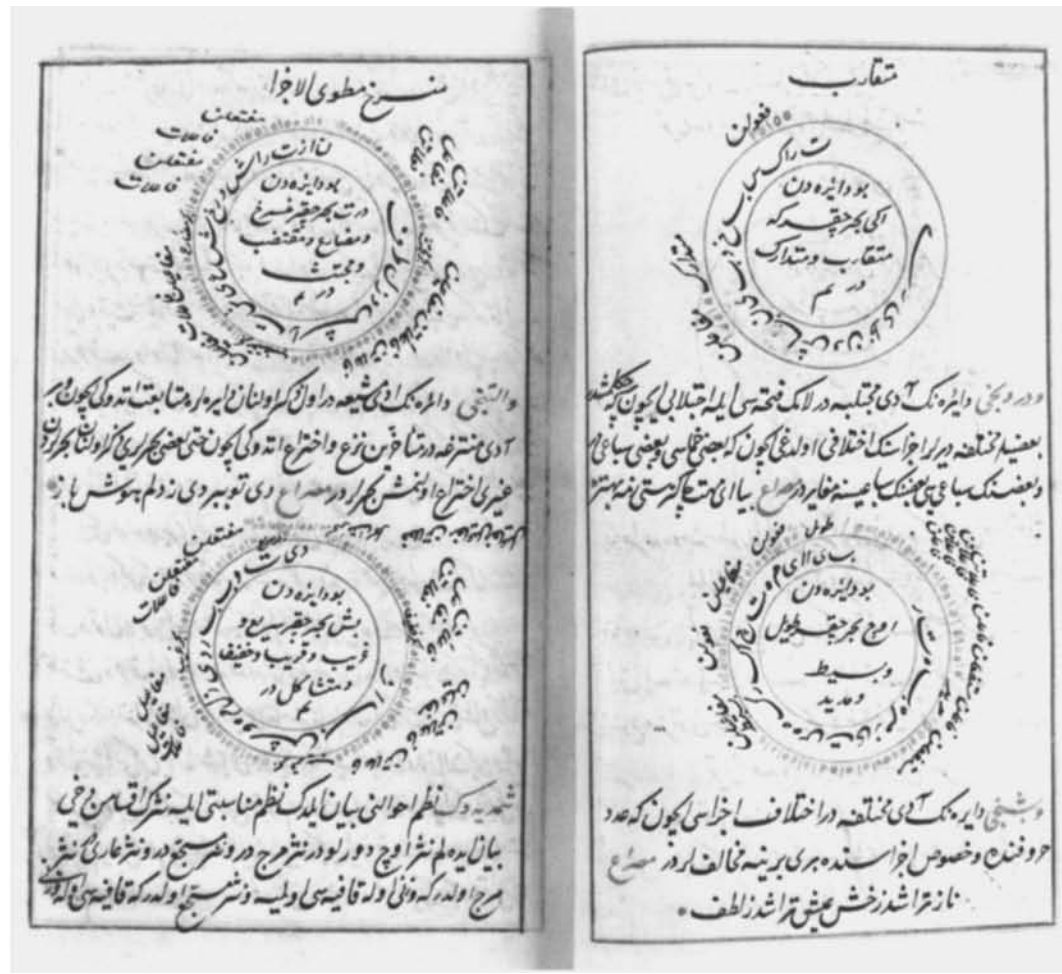
Ibn Khaldun, too, referred to molds functioning as deep structures that guide the "method" (*uslūb*) of poets, which was rooted in the science of metrics (*ᶜilm al-ᶜarūḍ*) with its codified meters (*wazn*) derived from an ideal scheme of circles regulating rhythmic patterns of sound (figs. 125, 126). The eighth-century Arab prosodist Khalil b. Ahmad al-Farahidi (or Farhudi) of Basra was the first to graphically represent the inner rhythmical structure of Arabic verse by means of five metric circles showing how the sixteen traditional meters are composed of different combinations of eight rhythmic feet. Using graphic signs (| and ○) for "quiescent" and "moving" consonants, Khalil arranged the feet around the periphery of these metric circles constituting fundamental modes or structural molds (*uṣūl,* pl. of *aṣl,* lit., "roots," or "bases"). The actual metric forms used by poets did not always correspond to the ideal sequence of consonants determined by the five circles; deviations from the norm formed acceptable variants (*furū*ᶜ, pl. of *far*ᶜ, lit., "branches") that had to obey a special set of complicated rules. This structural system of roots and branches, consisting of ideal meters and permissible deviations or variants, was sufficiently flexible to allow practitioners a good deal of scope. It was adopted by subsequent generations of Arab, Persian, and Turkish poets who only transformed its details. Referring to the structural molds used by poets, Ibn Khaldun wrote:

> It should be known that they use it to express the loom on which word combinations are woven, or the mold into which they are packed. . . . [Poetical method] is used to refer to a mental form for metrical word combinations which is universal in the sense of conforming with any particular word combination. This form is abstracted by the mind from the most prominent individual word combinations and given a place in the imagination comparable to a mold or loom. Word combinations that the Arabs consider sound, in the sense of having the [correct] vowel endings and the [proper] style, are then selected and packed by [the mind] into [that form], just as the builder does with the mold, or the weaver with the loom.[96]

In the case of the builder, Ibn Khaldun was probably alluding to molds used in shaping plaster or in making differently sized bricks based on modular cubit measures. He further elaborated the concept of abstract mental molds in a passage where he discussed word combinations and the position of individual words with respect to each other:

125. Muslih al-Din Mustafa Sururi, diagrams of metric circles representing rhythmic patterns of sound. From his *Baḥr el-maʿārif* (Sea of knowledge), written for the Ottoman prince Mustafa in 1549, copied in 1585, red and black ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS H. 659, fols. 16v–17r.

126. Muslih al-Din Mustafa Sururi, diagrams of metric circles representing rhythmic patterns of sound. From his *Baḥr el-maʿārif* (Sea of knowledge), written for the Ottoman prince Mustafa in 1549, copied in 1585, red and black ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS H. 659, fols. 17v–18r.



> This teaches a person the universal mold which he can learn through [constant] practice in Arabic poetry. [This universal mold] is an abstraction in the mind derived from specific word combinations, to all of which the [universal] mold conforms. The author of a spoken utterance is like a builder or weaver. The proper mental form is like the mold used in building, or the loom used in weaving. The builder who abandons his mold, or the weaver who abandons his loom is unsuccessful.[97]

These structural molds into which words are poured become firmly rooted in the poet's mind, just as a craft technique acquired after years of practice and memorization becomes habitual. Ibn Khaldun defined a craft as "the habit of something concerned with action and thought." For him "a habit is a firmly rooted quality acquired by doing a certain action and repeating it time after time, until the form of [that action] is firmly fixed" in the mind as a type of practical reason. Despite their mechanical rules transmitted through repeated instruction, then, the crafts involve the mental structures of the creative human soul since "habits are qualities and colors of the soul."[98] This recalls Ibn Sina's earlier classification of "habitual reason" or habit (*malaka*) as an abstractive power of the rational soul closely linked to "holy reason." It was only after a painstaking process of apprenticeship, required for internalizing traditional molds as effortless habits, that the naturally talented artisan was able to express inner creativity through them. To this end the Persian poet Nizami ʿAruzi advised aspiring poets in the twelfth century to memorize as many works by earlier poets as they could:

> But to this rank a poet cannot attain unless in the prime of his life and the season of his youth he commits to memory 20,000 couplets of the poetry of the Ancients, keeps in view [as models] 10,000 verses of the works of the Moderns, and continually reads and remembers the *dīwāns* of the masters of his art, observing how they have acquitted themselves in the strait passes and delicate places of song, in order that thus the different styles and varieties of verse may become ingrained in his nature.[99]

Ibn Khaldun's definition of poetry, which rigidly circumscribes artistic creativity within traditionally fixed norms engraved in the minds of artisans and comparable to a mold or loom, is in keeping with the use of structurally defined modes in other fields of artistic endeavor including music, which was closely linked with poetry. In his tenth-century treatise on music al-Farabi discussed the musical modes (*maqām*) in similar terms, emphasizing the necessity of long years of practice imitating earlier models until they become internalized in the musician's imagination as firmly fixed habits. It was only then that the artist with natural talent could begin to improvise without effort, just as in other arts such as rhetoric and poetics.[100] The process of musical creation, then, once again started with ideal forms abstracted by the creator's imaginative faculty; these mental abstractions were translated by notes into sensible analogues. Music could be sensible, imaginable, and intelligible, addressing the senses, the imagination, and the intelligence, respectively. Three types of musicians corresponded to each of these hierarchically ranked categories—those merely dependent on sense perceptions, those instinctively capable of imagination, and those able to intellectualize imaginary conceptions. Al-Farabi differentiated the psychological effects of music on the soul according to this tripartite order; the first type of music aroused agreeable sensations and simple pleasures, the second provoked passions, while the third addressed the imagination and intellect. The most perfect music was that which combined all three effects, inciting the listener to acquire higher spiritual beauties such as wisdom and knowledge.[101]

Al-Farabi divided the traditional rhythms of Arab music into two types: fundamental deep structures constituting seven basic modes and supplementary ornaments. He compared the first type to the use of warps and wefts in textiles, or of bricks and plaster in architecture; the second type corresponded to nonstructural decorative elements used in construction and weaving alike.[102] The transformation and modification of the seven fundamental musical rhythms generated innumerable variants, much like the *uṣūl* of poetry with their permissible rhythmic deviations classified as *furūʿ*. Differences in arrangement, repetition,

acceleration, or ornamentation engendered a multiplicity of rhythms, all of them derivatives of the seven basic modes. Permissible deviations from the ideal structures of fixed modes thus allowed for an almost infinite number of permutations through which musicians could demonstrate their inspired skill. The perfection or imperfection of note combinations in this modal system was comparable to the harmonious or discordant combination of colors and forms in visual designs.

Al-Farabi thus recognized a basic structural affinity among those crafts using modular units of composition in products that emphasized harmonious patterns. This parallelism among different media was also implied in the frequent use of craft metaphors by poets who likened themselves to the practitioners of other crafts, metaphors rooted in shared processes of artistic conceptualization and realization. Al-Farabi wrote that the formal elements of music are analogous to the number in arithmetic, the limit in geometry (e.g., the arc of a circle, or the side of a square), the syllogism in logic, the strophe in poetry, and the foot in metrics. Harmonization (consonance) played the same role in music as it did in the other arts based on the proportional combination of discrete elements.[103]

Al-Farabi's structural analysis curiously foreshadowed nineteenth-century European theories of the grammar of ornament, which stressed the analogy between music, poetry, and abstract visual patterns, all of them relying on a measured sequence of serial units governed by syntactic rules. Jones, for example, perceptively wrote that the seven basic modular units composing the muqarnas ceiling of the Sala de la Barca at the Alhambra generated "combinations as various as the melodies which may be produced from the seven notes of the musical scale."[104] The shared modular basis of geometric patterns, music, poetry, and calligraphy was further explored in el-Said and Parman's *Geometric Concepts in Islamic Art,* 1976. This structural affinity across different fields, frequently noted by the nineteenth-century Orientalists who attributed it to a specifically Arabo-Islamic mind-set, had more to do with a modal theory of aesthetics than with religion or ethnoracial character. Restrictions placed on figural representation by religious tradition no doubt had encouraged designers to channel their creative energies to develop elaborate systems of nonfigural patterning. Nevertheless the distinctive abstract visual idioms they formulated were informed primarily by an aesthetic theory that privileged the imagination's ingenious abstracting capacities over naturalistic representation. The modal system of aesthetics revolved around a notion of ideal deep structures that could be transformed endlessly to create variations and derivatives. It emphasized the artist's imagination, the place where these deep structures became permanently embedded as abstractions that engendered remarkably varied products capable of arousing a sense of pleasure and wonderment.

The Neoplatonic musical tradition, with its Pythagorean emphasis on cosmology and numerology, was largely ignored by such philosophers as al-Farabi and Ibn Sina, but it continued as a durable undercurrent. Initially explored by al-Kindi and perpetuated by the Brethren of Purity, cosmological affiliations would eventually crystallize in later centuries around particular musical modes. As Owen Wright pointed out, with the decline of systematic theory the dominant tradition became cosmological. Arabic, Persian, and Turkish musical treatises written between the fourteenth and eighteenth centuries almost invariably correlated the twelve melodic modes with the signs of the zodiac and "an open-ended series of natural phenomena" including the times of the day and the number of months.[105] Despite their longstanding usage well into the modern era the musical modes showed a remarkable capacity to resist the danger of ossification, allowing generations of musicians to improvise within their rhythmic cycles.

The idea of improvisation within a chosen grid of the *girih* provides a striking analogy to musical improvisation within a particular mode (*maqām*), to poetic composition within the disciplined structure of a given meter (*wazn*), and to calligraphic exercises conforming to codified modes of script based on fixed proportions. Such analogies once again point to a shared aesthetic sensibility uniting the various crafts concerned with rhythmically composing proportionally ordered, quantifiable parts (*juz'*), a sensibility that measured artistic skill (*hunar* or *maʿrifa*) against the codified rules of fundamental modes constituting self-contained design systems with a formal logic of their own. These modes, corresponding to ideal norms of beauty, regulated repeat patterns in different

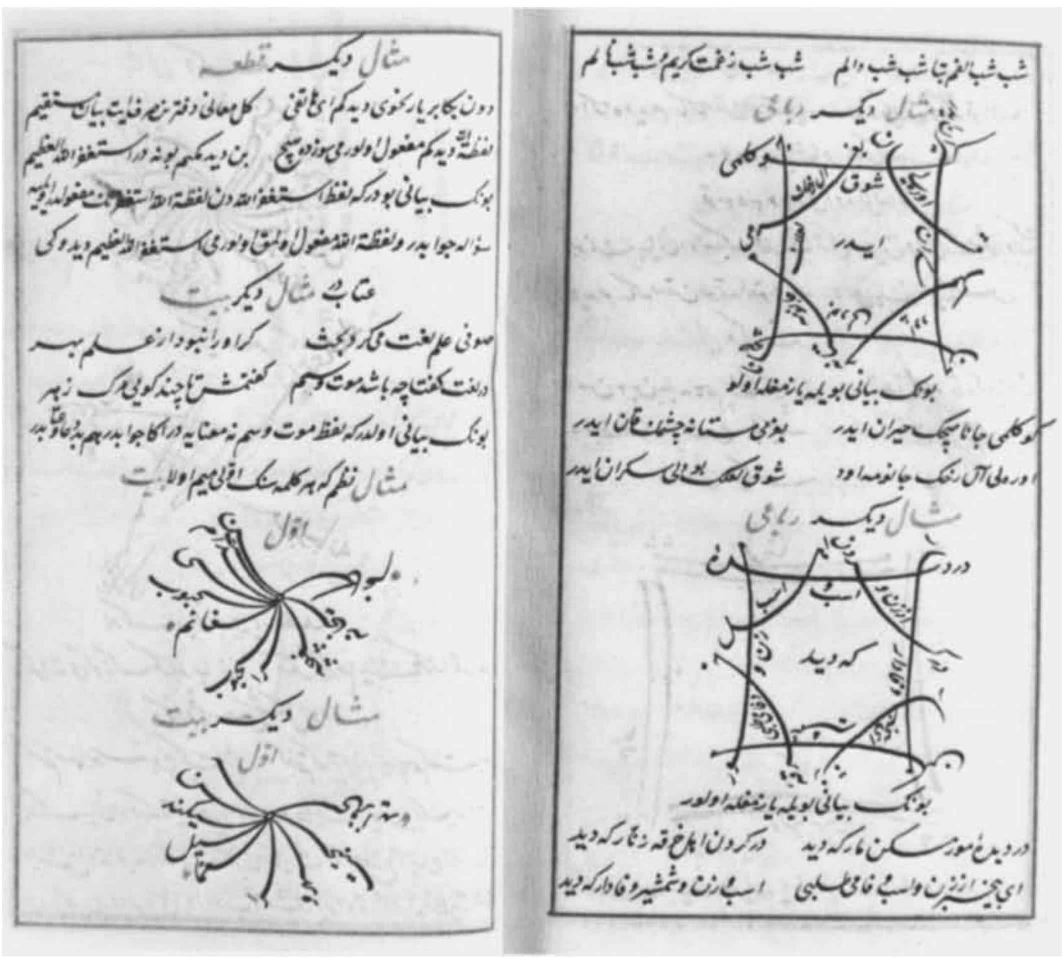
media by restricting their possible arrangement according to a predetermined syntax (figs. 127–129). That such a modal system was at work in the visual arts is clearly demonstrated by the Safavid sources cited in part 3 that refer to the seven fundamental modes (*aṣl*) of illumination and their numerous variants (*farʿ*), a classification seemingly inherited from the Timurid-Turkmen period.

These seven modes of abstract patterning, which constituted relatively autonomous design universes, can be seen as visual analogues aiming to produce the same kind of artificiality and pleasurable awe upheld in literary theory where imaginative creation (*takhyīl*) plays a central role. Nonnaturalistic designs reflected the superior abstracting capacities of the internal senses participating in the creative process. According to Ibn Sina, who defined perception as "the abstraction by the percipient subject of the form of the perceived object in some manner," geometric forms were among the purest mental abstractions involving the intervention of the internal senses. This widespread view was captured by the twelfth-century Ghaznavid poet Sana'i, who likened "the ability to behold the divine manifestation . . . to the intellectual way of perception of a geometrician." "When you have not learned about lines, planes and points," he said, you are restricted to seeing only with your senses.[106]

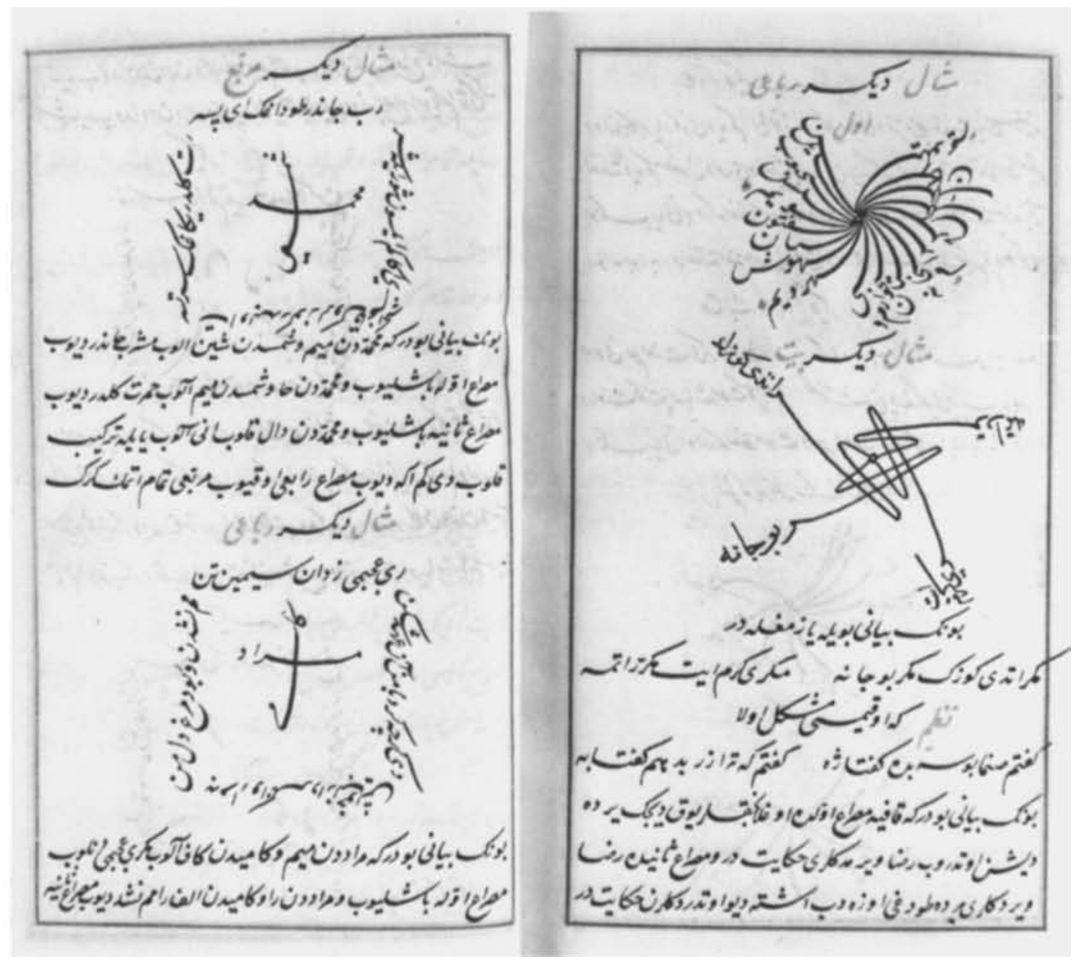
By implication geometrized designs (whether figural or nonfigural) and the purely geometric patterns of the *girih* mode constituted mental images that were inherently superior to naturalistic representations based on sense perceptions. Their aim was not to capture optically perceived reality, but rather to provide glimpses of the wondrous beauty imprinted in the imaginative artist's mind or soul. The "eye of the mind" fractured the unity of visual space by refracting it into an infinity of angles and brightly colored abstract shapes with no single focus. This insertion of subjectivity into the visual process accentuated the disjunction between internal and external vision, an aesthetic attitude that would be reversed in Renaissance Europe where these two types of vision became coordinated by perspectivalism, with its "neutral" gaze that separated subject and object. In that respect, the subjective "Baroque vision" that celebrated the dazzling, disorienting, ecstatic, and vertiginous experiences of mystical rapture came closer to the aesthetic sensibilities embodied in the *girih* mode. In the Baroque case, the "madness of vision" was linked to a transcendental aesthetics of the sublime that sought to "represent the unrepresentable" and to express a "yearning for a presence that can never be fulfilled." This Baroque celebration of "ocular madness" could produce ecstasy in some but bewilderment and confusion in others, much like the varied subjective responses to which the *girih* opened itself.[107]

The relative visual autonomy of Islamic nonnarrative abstract modes of design can also be seen as anticipating some aspects of abstraction in modern art. Mark A. Cheetham's *The Rhetoric of Purity*, 1991, argues that the notion of purity was central to the modernist rhetoric on geometric abstraction. Purity, he wrote, was singled out by such artists as Wassily Kandinsky (1866–1944) and Mondrian as the ultimate quality an abstract painting driven by a transcendental urge should possess. Influenced by Neoplatonism, the modern paradigm of transcendental aesthetic purity emphasized the abstracting power of memory, which enabled the artist to see through nature's veils.[108] This emphasis on memory as a noetic faculty that could yield access to higher forms of understanding inaccessible to the external senses provides a striking parallel to the role the inner senses play in medieval Islamic (and Latin Scholastic) texts dealing with the psychology of vision.

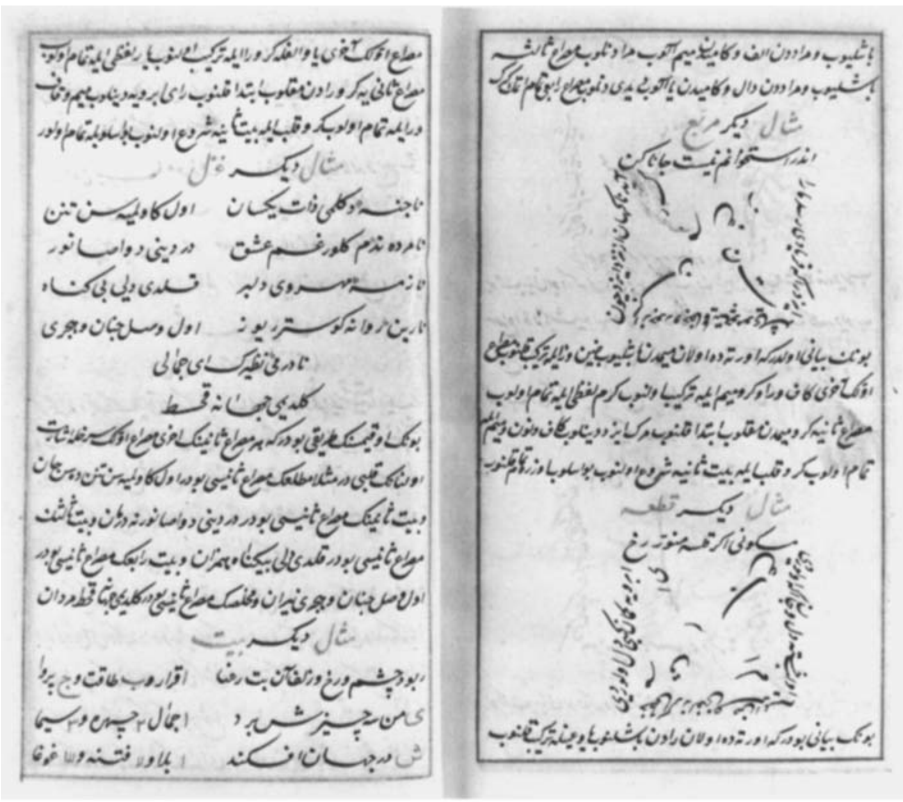
That this parallel may occasionally have been informed by an awareness of the Islamic visual tradition is not unlikely, given the nineteenth- and early twentieth-century fascination with abstract arabesques. Such a connection is implied by a theoretical tract, the so-called Turkish painter's manual, which the French artist Paul Gauguin (1848–1903) had lent to the painter Georges Seurat (1859–1891). This text attributed to the Turkish poet Sünbülzade Vehbi (d. 1809) advised young painters that "it is better to paint from memory [*peindre de mémoire*]" and recommended a self-conscious rejection of external appearances. Sünbülzade instructed pupils to give shape to abstract designs and unreal primary colors "within the mold of a theory prepared in advance in your brain [*dans le moule d'une théorie préparée à l'avance dans votre cerveau*]," a statement that



127. Muslih al-Din Mustafa Sururi, diagrams of pattern-forming verses. From his *Baḥr el-maʿārif* (Sea of knowledge), written for the Ottoman prince Mustafa in 1549, copied in 1585, ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS H. 659, fols. 134v–135r.



128. Muslih al-Din Mustafa Sururi, diagrams of pattern-forming verses. From his *Baḥr el-maʿārif* (Sea of knowledge), written for the Ottoman prince Mustafa in 1549, copied in 1585, ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS H. 659, fols. 135v–136r.



129. Muslih al-Din Mustafa Sururi, diagrams of pattern-forming verses. From his *Baḥr el-maʿārif* (Sea of knowledge), written for the Ottoman prince Mustafa in 1549, copied in 1585, ink on paper. Istanbul, Topkapı Sarayı Müzesi Kütüphanesi, MS H. 659, fol. 136v.

curiously recalls references by earlier Muslim writers to abstract molds engraved in the minds of artists. It is noteworthy that the authority of the Islamic visual tradition was invoked to legitimize modern abstract painting in this theoretical tract, which according to Cheetham carries "crucial implications for the nature and development of abstract art from the time of Gauguin's early experiments well into the twentieth century."[109]

As Hodgson wrote, the predominantly aniconic character of the Islamic visual tradition had inspired architects and artists "to create a new world of the imagination . . . rich in its own expression of wonder and delight." The artistic preoccupation with wonder and amazement is a leitmotiv in post-Mongol sources on painting. For example, in his account of outstanding late Timurid painters the Turko-Mongolian prince Mirza Muhammad Haydar Dughlat (1499/1500–1551) referred to Shah Muzaffar's fine brush that "possesses such grace and maturity that the eye of the beholder is astonished." He described the amazing skill of the illuminator Mawlana Mahmud, who prepared an elaborate frontispiece for Sultan Husayn Bayqara, in similar terms: "He labored on it for seven years and made it so intricate *(barik)* that in the joints of the *(band-i rumi)*, each of which may be half a chickpea in size, he has made of gold a yellow *yakmaha* (?) [such that?] fifty *islimi* tendrils can be counted." In his preface to the Bahram Mirza album prepared in 1544, Dost Muhammad wrote, "If a form is not worthy of astonishment, it is not worth a touch of the brush." He often described paintings and illuminations as feats that "dazzle the eyes" of "people of insight" who cannot help being "amazed and astounded" by them.[110]

The prefaces of Safavid albums of calligraphic specimens and painting samples, which link the fields of calligraphy, illumination, and narrative painting, are shorter versions of biographical treatises on painters and calligraphers. This new post-Mongol biographical genre, reflecting the close cooperation between miniature painters, illuminator-decorators, and calligraphers in the court scriptoria (*kitābkhāna* or *kutubkhāna*) of the Ilkhanids and their successors (the Timurid-Turkmen, Safavid, Uzbek, Ottoman, and Mughal dynasties), signals the emergence of a "literati" sensibility in the visual arts, possibly inspired by Ilkhanid contacts with Mongol China. It was in this unique context that the arts of the book received unprecedented court patronage in the Turco-Iranian world where the aesthetic sensibilities of illuminator-decorators, miniature painters, calligraphers, and literati became synchronized under a single institutional framework that gave a distinctive coloring to artistic production in the post-Mongol eastern Islamic lands. The intimate dialogue among painting, calligraphy, and literature is captured in a petition letter of Ahmad b. ʿAbd Allah al-Hijazi where he traces his career from Timurid Shiraz in 1422 to Ottoman Edirne in 1441–1442. After pointing out that he began his training by studying poetry according to the dictum "Poetry is necessary" and by learning

calligraphy, which is "half of learning," he went on to describe his other skills:

> In the *kutubkhana* of each of these [Timurid rulers, that is, Ibrahim Sultan, Baysunghur, Ulugh Beg, and Shahrukh Mirza] there was a group of learned people without equal in the world—copyist, illuminator, illustrator, binder. I too laid some small claim [to proficiency] in these arts by virtue of my aspiration and ardour, and through service and apprenticeship I acquired from every harvest a gleaning, and from every gleaning a seed, until during a voyage, I arrived in the year 845 in Edirne.[111]

It was in this type of setting that the *girih* mode continued to be elaborated during the Timurid-Turkmen period, a setting where painters and calligraphers employed in court scriptoria were often skilled in poetry. They were the ones who prepared designs for architectural projects, designs that would have accompanied the two- and three-dimensional geometric patterns of the Topkapı scroll. Unlike the royal ateliers of the Abbasid caliph al-Muᶜtadid's early tenth-century palace in Baghdad discussed in part 3, where the theoreticians and practitioners of all the arts and sciences were gathered together, the post-Mongol scriptoria privileged literary culture over science. The unprecedented emphasis on literature and art in the Timurid-Turkmen *kitābkhāna*s finds a striking parallel in the fifteenth-century European courts of the Renaissance, a period with a different cultural orientation than that of the so-called twelfth-century renaissance of Europe, with its focus on philosophy and science. The primacy of the arts of the book and literature nourished the growing affinity between visual aesthetics and literary theory in an age when inscriptions quoting Persian poems came to occupy a prominent position on religious and secular monuments alike. The aesthetic value attached to pleasurable wonder in the post-Mongol biographies of calligraphers and painters is also encountered in contemporary literary criticism, which favors the stimulation of emotions in the reader rather than the objective representation of an external reality.

The intimate association in literary theory between pleasure, wonder, and the imagination can be traced back to the poetics of al-Farabi and Ibn Sina, both of whom stressed the subjective nature of aesthetic experience. Ibn Sina, who described poetry as imaginative speech, wrote that imaginative assent to poetic utterances "is a kind of compliance due to the wonder (*taᶜajjub*) and pleasure (*ladhdha*) that are caused by the utterance itself."[112] In his Aristotelian theory of Arabic poetics the Maghribi literary critic al-Qartajanni (1211–1285) identified three types of mimesis in imaginative creation (*takhyīl*):

> Poetry is metrical, imaginatively-creative discourse, characterized in the Arabic language also by the inclusion of rhyme. The imaginatively-creative premises it combines, whether objectively truthful or false, have as their only conditions, insofar as they are poetry, imaginative creativity. . . . All this must be [realized] by a mimetic representation of the usual by the usual, the strange by the strange, or the strange by the usual. And the closer the object is to that by which it has been mimetically represented, the clearer will be the similarity; on the other hand, the more strangeness and wonder are added to the imaginative creation, the more original it will be.[113]

Between the two poles of naturalistic and fantastic representation extended a varied spectrum of approaches to mimesis. Among them, al-Qartajanni, like many Muslim literary critics, preferred the originality of "strangeness" and "wonder" to "similarity." The more artificial and removed from likeness to observed nature, the more artistic was poetic discourse considered.[114]

After all, etymologically the notion of art (*ṣanᶜat*) does imply artificiality (*ṣunᶜī* or *taṣannuᶜ*). The mimesis that al-Qartajanni considered to be creatively imaginative was not one that truthfully reproduced reality but one that transformed it to arouse subjective feelings of pleasurable awe and astonishment. Imaginative representations possessed an element of wonder that truth lacked; they were capable of inciting emotional responses distinctive to human beings with a spiritual and

intellectual capacity. Wonder, a prelude to philosophizing about something incompletely understood, is referred to in Plato's *Theaetetus* and Aristotle's *Metaphysics* as the starting point of philosophy. This became a commonplace notion in the Islamic world where Ibn Sina defined wonder as a first step toward fuller understanding and wisdom.[115] Neither he nor al-Farabi, however, reduced wonder to a mere means of furthering knowledge. Their poetics, like those of their successors, stressed the independent aesthetic value of pleasurable awe in and for itself while also recognizing its potential relation to further knowledge.[116] This was also the case with imaginative visual representations.

The Timurid-Turkmen world continued to be bound by traditional modal systems in poetics, music, calligraphy, and abstract illumination. Despite the increasing naturalism of the post-Mongol aesthetic synthesis in the eastern Islamic lands, the codified schematism of inherited design traditions continued to prevail. The purely geometric logic of the hermetic design world depicted in the Topkapı scroll is an example of that continuity. Much as the musical and poetic modes had become permeated with mystical and cosmological connotations, an increasing preoccupation with Sufism and cosmology characterized the Timurid-Turkmen architectural inscriptions discussed in part 3, inscriptions through which two- and three-dimensional *girih* patterns often were charged with specific messages. Working within the codified molds of a modal system of geometric patterning, Timurid-Turkmen master builders were able to create an original revetment aesthetic just as contemporary poets and musicians continued to recast traditional modes into new expressions. The endless permutations and modal variations of familiar patterns in the Topkapı scroll explored the limits of a traditional design system endowed with a new sense of theatricality in Timurid-Turkmen monumental architecture.

Like contemporary poets who creatively transformed traditional poetic models through rhetorical elaboration, Timurid-Turkmen builders and their teams of decorators sought to endow the canonical forms of the *girih* mode with a distinctive flavor of their own. Poetry, the most prestigious cultural undertaking of that age, engaged both the ruling elite and the urban populations (including artisans such as engravers, painters, calligraphers, and musicians who had achieved recognition as poets). Its preoccupation with "lavish rhetorical embellishments" and "ornamentation" has been judged negatively by modern critics such as Elias John Wilkinson Gibb, who wrote that Timurid-Turkmen poetry was "marred by an excessive use of rhetoric," summarizing its features as "subjectivity, artificialness and conventionality, combined with an ever increasing deftness of craftsmanship and brilliance of artistry." Jan Rypka similarly assessed the poetry of that period, from 1400 to 1520, as "marked by a cultivation of hollow rhetoric and slavish imitation" and an activity that "degenerates into a cult of affected artificiality."[117]

More recently Eva Maria Subtelny and Paul Losensky have presented a more sympathetic interpretation by placing Timurid-Turkmen poetry in its proper cultural and historical context where imitation and intertextuality were most highly valued. Subtelny wrote that imitational poetry "was the means by which a poet established himself within the collective Persian literary tradition which, by the fifteenth century, had become an intricate web of interrelationships and interdependencies between poets of different generations and distant localities." Correlating the increasing preoccupation with imitation, which had become "the touchstone of the poet's skill," and the growing intricacy of taste in Timurid-Turkmen poetry, she observed that the conservative dependence "on the elaboration of set themes dictated by convention" had of necessity turned "refinement of expression" into a "prime focus."[118] According to Losensky, too, it was a "conservative process of cultural self-definition" that had resulted in a poetic practice that was preoccupied with collecting, preserving, and consolidating the literary past. This was a "poetry that celebrates and revels in its own systematic conventionality" and "is by nature somehow static and catalogue-like" in its display of all the "elements and codes that constitute the poetic tradition." Losensky noted that the "Timurid penchant for standardization, repetition, and refinement" in the visual arts was equally paramount in the literary arts.[119] The same tendencies can be identified in the Topkapı scroll, which represents the culmination of a medieval design tradition rather than a new artistic direction.

The Timurid-Turkmen literary tradition informed taste patterns in other fields of artistic

endeavor, including the visual arts and architecture with their dependence on the *kitābkhāna* institution noted for its "ability to absorb and codify earlier traditions." Thomas W. Lentz and Glenn D. Lowry noticed a parallel between contemporary poetry and the visual "interest in the rhetorical elaboration of repeated patterns."[120] Dawlatshah's *Tadhkīrat al-shuᶜarā'* (Memoirs of poets), completed in 1487, acknowledged that tastes had changed and "the style of the ancients" was no longer a valid criterion for contemporary literary criticism. He made the following comment about the incongruity of the simple style of a tenth-century poet and the more elaborate tastes of his own day:

> The fact will seem strange to the intelligent that this verse is plain (*sādah*) and devoid of rhetorical devices and embellishments (*ṣanāyiᶜ va badāyiᶜ*) and vigor of style (*matānat*), for, if a poet were to present poetry like this at an audience of sultans and amirs nowadays, it would be rejected by his contemporaries.[121]

Similar aesthetic judgments were made by other Timurid biographer-critics, such as Nawa'i and Jami, in their *tadhkīras* that according to Subtelny "capture the very essence of the affected refinement and formal intricacy (at times, even forced mannerism) of the poetry of the late Timurid period."[122]

The master builders who around the same time designed the Topkapı scroll's *girih*s also seem to have felt that earlier examples of two- and three-dimensional geometric patterns were somewhat outdated. Their emphasis on refined sophistications, achieved by infinitely elaborating and fragmenting standard schemes into star-studded intricate webs that at times acquire an almost manneristic flavor, provides a striking parallel to contemporary poetic tastes. The self-consciousness of this taste for artful refinements with dazzling displays of complexity is captured in the inscription of a muqarnas projection from the Tashkent scrolls, where the draftsman challenged his colleagues to decipher his ingenious composition by counting its tiers (see fig. 13). This rare inscription once again reflects the designer's pride in his own creation that turns the bravura muqarnas composition into a kind of visual puzzle, a cerebral geometric game celebrating technical virtuosity. It recalls the preoccupation of contemporary poets with composing elaborate riddles (*muᶜammā*, lit., "enigma") whose verbal acrobatics were formal exercises in complexity.[123] The inscription sets the general tone of the Tashkent and Topkapı scrolls, whose repertory of complex *girih*s displays an attempt at brilliant performance and at outdoing earlier models. The taxing *girih*s compiled in these scrolls, which conspicuously omit simpler polygonal patterns, therefore can be seen as visual analogues to the exaggerated rhetorical flourishes so prized in Timurid-Turkmen poetry with its taste for the intricate.

The Topkapı scroll's geometric *girih*s, often accompanied on Timurid-Turkmen buildings with a variegated repertory of patterns derived from the seven modes of abstract illumination and from the codified scripts, subsumed medieval aesthetic notions revolving around the pure qualities of geometric harmony, light, and color. Although it is difficult to judge whether Timurid-Turkmen architects and decorators were aware of the philosophical speculations that had surrounded the early medieval context in which the *girih* mode was invented, there is no doubt that they had fully internalized a sophisticated geometric sensibility transmitted over the generations by scrolls and workshop practices, complemented by copies of earlier practical geometry manuals. Whatever their theoretical and philosophical background may have been, how could the perfectly proportioned geometric *girih*s of the Topkapı scroll, meant to be executed in a variety of differently textured materials bathed in vibrant colors, fail to aesthetically move even the most visually illiterate audiences?[124] These technically refined and visually arresting *girih*s represented the final flowering of a long-lived medieval tradition in which Christian and Muslim architects shared the firm conviction that the proper geometric formulas assured both the aesthetic effectiveness and the structural correctness of a building.

Though rooted in the traditional *girih* mode, the Timurid-Turkmen revetment aesthetic codified in the Topkapı scroll took on a highly distinctive appearance, becoming a recognizable stamp of identity associated with the ruling elite's architectural patronage. As Lentz and Lowry wrote:

> In exploiting older indigenous traditions and the kitabkhana model, the Timurids produced ever more exhilarating results in the decoration of larger expanses of surface. Familiar patterns were recreated, but the increased scale of the visual field endowed these schemes with a force not present in smaller formats. . . . As Timurid painting makes evident, the cumulative impact of these schemes in architecture, costume, carpets and tents effectively idealized royal spaces. A similar transformation frequently occurred in Persian poetry in which the natural world was transformed into a luxurious, artificial setting. These transformations of the physical world suggest . . . a deliberate analogy between a stylized contrived realm and the exclusive domain of the princes.[125]

Buildings lavishly sheathed with extensive revetments in the new visual idiom signified prestige, wealth, and privileged access to skilled court architects and decorators. Their labor-intensive, precious decorative skins functioned as robes of honor commensurate with the relative status of architectural patrons. The Timurid-Turkmen revetment aesthetic was used not only in buildings commissioned by the members of the ruling elite but also to transform earlier Islamic monuments. The powerful patron of the arts Nawa'i, for example, is known to have undertaken several restoration projects that symbolically appropriated old monuments through the addition of new decorative skins. Among the monuments he restored was the Masjid-i Jami^{c} in Herat, whose courtyard and entrances, between 1497 and 1499, received mosaic tiles that had become the unmistakable hallmarks of the Timurid revetment aesthetic.[126]

Architectural revetments, then, not only aroused subjective emotional responses but also acted as powerful identity markers that made the ruling dynasty's monuments and territorial boundaries legible. The Timurid-Turkmen decorative idiom embodied a desire to be identified with a preestablished visual tradition whose conventions were creatively manipulated. By contrast, in the post-Timurid era innovative abstract visual idioms boldly departing from the bondage of the past would be developed by imperial court cultures conscious of their distinctive dynastic identities. The territorial and cultural boundaries of these competing Islamic states were marked conspicuously by increasingly differentiated sign systems ranging from costumes to official modes of ornament uniting various luxury crafts. While the smaller frontier states of the early modern Islamic world, such as the Uzbeks of Central Asia and the sharifs of Morocco preferred to use architectural revetments displaying retrospective tendencies, the Ottomans, Safavids, and Mughals invented individualized visual idioms that could hardly be confused by contemporaries (see figs. 94–98). Earlier decorative patterns were preserved, but their intensity changed as they became inte-

grated into new grammars of form and color that departed from traditional Timurid-Turkmen precedents. The distinctive decorative revetments of these three empires, which remained strictly confined to the geographic boundaries controlled by each political entity, contributed to a heightened sense of cultural identity.

The period approximately extending between the sixteenth and eighteenth centuries displayed what may be called a protomodern ethos characterized by growing "secular" tendencies and the relative desacralization of the public sphere, an increasing independence from traditional culture, and at the same time a reluctance to sever ties from the past. Signs of confident change appeared everywhere, including literary criticism, which continued to uphold imitation but now began to emphasize creative departures from the cumulative weight of tradition. The fermentation of the old and new in both visual aesthetics and poetics involved a simultaneous acknowledgment of debt to the past and a boasting of mastery over the new.[127] Losensky identified an outspoken spirit of innovation in Safavid-Mughal poetics, with its "aesthetics of the new," which differed from the "consolidating and systematizing impulse" of the largely conservative outlook of the Timurid-Turkmen period. He quoted the following poems by Mughal and Safavid poets as examples of the new doctrine of originality:

> So that poetry might be adorned by
> you, there must be new meanings
> and old words.
> Advance on the path of your heart and
> don't turn back—don't go circling
> around someone else's poetry. . . .
> Abandon others' imaginations, for
> calling an adopted boy "son" does not
> make him one.
> Be happy with what God has given:
> Be a seeker of God-given meaning.
>
> —*Abu al-Fayz Fayzi* (d. 1595–1596),
> Akbar's poet laureate

> If the market for poetry's wares is
> depressed these days, Kalim, make the
> style fresh so it catches the buyer's eye.
>
> —*Abu Talib Kalim of Kashan* (d. 1651),
> Shah Jahan's poet laureate

> Writers consider me the master, for from
> meanings and words
> I have brought out the fresh style, not the
> ancient manner.
>
> —*Sa'ib of Tabriz* (1603–1677),
> Shah Abbas II's poet laureate

The quest for innovation would result in the invention of a distinctive "fresh idiom" or style (*shīwa-i tāza* or *ṭarz-i tāza*), generally known as Indian (*sabk-i Hindī*), that evaluated, revised, and re-created the Timurid-Turkmen poetic tradition.[128] Its repercussions were also felt in the Ottoman world where literati displayed a similar interest in stylistic novelty and in the invention of fresh images.[129]

According to Losensky it was "precisely the acute awareness of the accomplishments of their literary predecessors that gave such urgency to the Safavid-Mughal poet's call for originality," expressed by an increasing reliance on direct divine inspiration as a source for poetic freshness.[130] A similar attitude is encountered in the *Qānūn al-ṣuwar* by Sadiqi Bek, who discouraged Safavid miniature painters specializing in narrative figural painting from imitating earlier models and urged them to turn directly to nature for guidance: "In this particular genre, only a fool would think to parody the works of the past great masters; the results could only be a self-inflicted belaboring over a pointless pastiche (*tatabbu*ᶜ). Moreover, whether there has already been a Mani and a Bihzad, how else [except through the direct observation of nature] could one break free of the crushing weight of past perfection?"[131]

Although Sadiqi Bek recommended that illuminators imitate conventional abstract modes, there, as in narrative miniature painting, one could sense the development of a somewhat more naturalistic sensibility that culminated with the subordination of the rigidly geometric *girih* mode to a predominantly vegetal aesthetic in the Safavid court. The invention of seminaturalistic vegetal-floral decorative idioms in the court ateliers of the three early modern empires signaled changing patterns of taste that relegated the cerebral acrobatics of geometry to a minor role (see figs. 94–98). The

fallen cultural prestige of geometry is captured in Sünbülzade's eighteenth-century versified book of advice addressed to his son: "Do not esteem geometry, / Avoid getting caught in that circle of distraction." In addition to reflecting the increasing naturalism of the early modern ethos, the new idioms of ornament articulated self-consciously forged dynastic identities through the creation of hegemonic "visual regimes."[132] The conspicuous marginalization of angular geometric surface revetments by curvilinear vegetal patterns in the classical Safavid style of the late sixteenth and seventeenth centuries served as a boundary marker between the contested Safavid and Uzbek territories in Khurasan beyond which the predominantly geometric Timurid visual idiom prevailed.

A similar aesthetic boundary had been created in the second half of the sixteenth century between the Safavid and Ottoman domains. The emergence of the classical Ottoman style in the 1540s and 1550s precisely at a time when the two rival powers were bitterly torn by ideological and military conflict partly explains the diminishing receptivity to Persianate architectural revetments in those years. The predominantly floral decorative vocabulary invented in the Ottoman court ateliers at that time was applied in bold color schemes to such varied media as underglaze Iznik tiles, wall painting, manuscript illumination, painted woodwork, textiles, tents, carpets, metalwork, and stone carving. Buildings, furnishings, and luxury objects with a unified decorative skin projected a recognizable Ottoman dynastic image. This cohesive system of canonical signs, created in the court milieu of the capital Istanbul and primarily associated with the ruling elite, played an important role in visually cementing the vast realms of the empire.[133]

The consolidation of the classical Mughal visual idiom during the reign of Shah Jahan was also characterized by a departure from Persianate models and the formulation of a floral aesthetic partly inspired by European herbals. The rigid angularity of interlocked polygons and stars once again was displaced by curvilinear forms displaying an unprecedented degree of naturalism. The Mughal court historian Muhammad Salih Kanbu pointed out that certain monuments built at Peshawar in a Persianate style under the supervision of the Persian noble ᶜAli Mardan Khan (who had defected from the Safavid side to the Mughal court in 1638) were not approved by Shah Jahan, just as some repairs at the Red Fort in Lahore under the supervision of Wazir Khan (whose own brick mosque in Lahore, completed in 1634, is decorated with traditional tile revetments and painted plaster decorations) were judged to be unpleasing in style.[134]

The novel Mughal floral revetment aesthetic, fully codified around that time under Shah Jahan's imperial initiative, was no longer responsive to Persianate models that had been cultivated enthusiastically up to that point to articulate the memories of a Timurid past. This aesthetic development proudly asserting an independent dynastic identity once again took place in a context of intense cultural rivalry and military conflict with the neighboring Safavids over contested territories in the Afghan border, precisely the same type of setting in which the Ottomans had self-consciously codified their own dynastic image almost a century earlier. Once the "fresh style" of the Mughal court was formulated, many of the antiquated red sandstone buildings in the Red Forts in Agra and in Lahore were demolished and rebuilt in the new white marble idiom with precious inlaid or low relief flowers. The intended naturalism of floral inlays can be deduced from Kalim's description of the Taj Mahal:

> The inlayer has set stone within stone,
> As bold and precise as the dark spot
> within the tulip's heart.
>
> Pictures become manifest from every
> stone;
> Take a look at the garden in the mirror.
>
> They have inlaid stone flowers in marble,
> Which surpass reality in colour if not
> in fragrance.[135]

This description, referring to the superior reality reflected in the mirror of the designer's mind or soul, shows that despite its increasing naturalism the Mughal visual idiom was still bound to a conventional modal system of aesthetics. Like contemporary poets who introduced fresh images into the vocabulary of poetry without radically transforming the metric system they had inherited, Mughal artists expanded their visual repertoire with semi-

naturalistic forms conforming to the traditional classification of fundamental design modes. Floral patterns based on similar color schemes unified the artistic products of the Mughal court ateliers, particularly tents, textiles, carpets, wall paintings, illuminated manuscripts, and precious objects that accompanied architectural settings.[136]

The widespread early modern practice of removing the surface revetments of earlier Islamic monuments and replacing them with new ones was not aimed merely at beautification. Some examples, such as Sultan Süleyman I's replacing the exterior mosaics of the Umayyad Dome of the Rock with Ottoman tile revetments (he similarly transformed the surfaces of the major Muslim shrines in Mecca and Medina when they came under his control) or Shah Tahmasp's providing the Great Mosque in Isfahan (the ultimate symbol of Sunni orthodoxy during the Seljuq period) with tile revetments in the Safavid style carrying Shiᶜi inscriptions, are sufficient to demonstrate the ideological signifying power of architectural ornament. Decorative revetments, which often used a rigidly restricted canonical vocabulary that was immediately recognizable, functioned as emblematic identity markers visually expressing shifting cultural, sectarian, and political boundaries.

The same kind of visual discourse relying on the subtle manipulation of abstract sign systems was no doubt operative during the less documented formative period of Islam, though scholarship has deemphasized it by favoring unity over diversity. Perhaps the distinctions were not as clearly articulated then as they were in the early modern era, but still the semiotic potential of architectural ornament could hardly be ignored. For example, one of the radical shifts in early Islamic visual culture was the transformation of the sober aesthetic, developed around the locus of Medina at the time of the Prophet and the egalitarian early caliphs who openly dissapproved of costly architecture, into the lavish imperial iconography of the Umayyads, an innovation opposed by the Medina aristocracy and later by recurring puritan movements that would culminate by the mid-eighteenth century in Wahabism, with its intense aversion to luxurious ornament and royal architecture.

That the Umayyad architectural and decorative idiom, developed by rulers who had transferred the seat of caliphal power from Medina to Damascus, was read by traditional circles as a conspicuous departure from old norms is clearly implied in the sources. During his extravagant rebuilding campaign of the Prophet's mosque in Medina with Byzantine-flavored mosaic revetments resembling those used in the Great Mosque in Damascus (see fig. 81), the Umayyad caliph al-Walid I (r. 705–715) had reportedly boasted to the son of the third caliph, ᶜUthman (who had enlarged the same mosque in the mid-seventh century), "How much our mosque surpasses yours!" ᶜUthman's son allegedly replied, "Certainly, but that is because we built it after the style of the old Arab *masjids*, and you after the style of Christian churches."[137] This imagined dialogue, most likely invented to express later anti-Umayyad sentiments, nevertheless captures the ideological associations of visual forms. The Umayyad architectural style developed in Syria (a land rich with late antique and Byzantine monuments) was not only capable of challenging the modest architecture of the early caliphs but also the extravagant imperial monuments of the neighboring Byzantines. A well-known passage by the tenth-century author Muqaddasi (the grandson of an architect) shows that competition with the splendor of lavishly decorated Syrian churches such as the Holy Sepulcher in Jerusalem and those of Lydda and Edessa was one of the central motivations behind the ambitious programs of Umayyad imperial monuments, with their extensive mosaic revetments.[138]

The early Abbasid caliphate, too, eventually developed its own system of abstract visual signs, though the pitifully few monuments remaining from that time do not allow us to fully reconstruct its evolution. It culminated in the distinctive Samarran beveled style whose many local variants unified and gave greater visual coherence to the vast Abbasid realms (see figs. 84–87). The abstract sign systems subsequently formulated by the three rival early Islamic caliphates, that is, the later Abbasids, the Fatimids, and the Spanish Umayyads, constituted a seemingly unified visual culture clearly distinguishing the *dār al-Islām* from its non-Muslim neighbors. Nevertheless, as the geographic confinement of the *girih* at that time (and subsequently during the Sunni revival) to the territories of the Abbasid caliphs and their vassals

shows, the ornamental idioms of each caliphate were subtly differentiated, not unlike those of the three early modern empires. It was not visual similarity, but difference, that communicated contested religiopolitical ideologies within the extensive Muslim domains whose internal boundaries were marked by constantly shifting abstract sign systems capable of conveying semiotic messages to insiders who were familiar with culturally determined codes of recognition. Despite their apparent unity, these visual signs hardly constituted a homogeneous "Islamic" style with fixed horizons; discontinuities and ruptures resulted in a lively spectrum of competing paradigms.

Hegemonic sign systems were formulated in major urban centers that often coincided with dynastic capitals, since the main driving force of paradigmatic shifts in Islamic architecture and decorative revetments was caliphal or royal patronage. As Ibn Khaldun noted, it was the patronage provided by ruling dynasties that nourished not only monumental architecture but also the increasing variety of luxury crafts in particular urban centers characterized by their highly developed sedentary culture. These centers were prosperous capitals and a network of other cities where the dynasty was "at the root of" cultural patronage:

> It is the ruling dynasty that demands crafts and their improvement. It causes the demand for them and makes them desirable. Crafts not in demand with the dynasty may be in demand with the other inhabitants of a city. However, that would not be the same thing, for the dynasty is the biggest market. There, everything can be marketed.[139]

According to Ibn Khaldun the perfection of the luxury crafts and the patronage of monumental architecture was proportionate to the power of royal authority in certain cities.[140] Painfully aware of the more advanced nature of sedentary culture in the eastern Islamic world in comparison to the Maghrib during his own time, he wrote:

> It is true that the old cities, such as Baghdad, al-Basrah, and al-Kufah, which were the [original] mines of scholarship, are in ruins. However, God has replaced them with cities even greater than they were. Science was transplanted from the [early centers] to the non-Arab ᶜIraq of Khurasan, to Transoxania in the East, and to Cairo and adjacent regions in the West. These cities have never ceased to have an abundant and continuous civilization, and the tradition of scientific instruction had always persisted in them. The inhabitants of the East are, in general, more firmly rooted in the craft of scientific instruction and, indeed, in all the other crafts [than Maghribis].[141]

This fourteenth-century picture, dominated by the Mamluk and Timurid capitals, would once again change in the early modern era when different cities emerged as cultural centers from which new dynastic tastes were disseminated. According to Taᶜlikizade, for example, the major urban metropolises of the sixteenth century were Ottoman Istanbul, Cairo (now under Ottoman rule), Safavid Tabriz, Mughal Delhi, Rome, and Beijing, a list reflecting the reconfiguration of political power that had marginalized earlier Timurid cultural centers in Khurasan and Central Asia.[142]

It was in such shifting dynastic urban centers that distinctive architectural and decorative idioms often emerged all at once, without the usual evolutionary process of development, and gave a clear visual expression to changing identities. Canonical surface revetments played a central role in this process. Newly formulated decorative skins immediately transformed the surfaces of a wide variety of objects, regardless of particular media, to create a sense of cultural homogeneity within hegemonic political formations that brought together a wide variety of ethnic, religious, cultural, and linguistic components. Though visual subcultures (both Muslim and non-Muslim) often coexisted with these dominant visual regimes, they generally had a low degree of conspicuousness. The adoption or rejection of specific canonical visual idioms in neighboring satellite states was often a semiotically charged, conscious expression of political allegiances, modified by local traditions and collective memories.

As such the visual regimes that became domi-

nant in various historical junctures were neither universal expressions of timeless Islamic doctrines nor regional dialects determined by geographic-climatic or ethnoracial factors. Their fluctuating mechanisms were regulated by the patronage patterns of multinational and multiregional empires or caliphates that significantly differed from the modern nation states occupying those regions today. Whether they were ruled directly by a centralized dynasty or constituted decentralized yet culturally unified loose confederations of "city-states" (as in the case of the Sunni revival), the rhythms of these political configurations have not yet been correlated with corresponding ornamental idioms in the art-historical literature.[143] The dominant paradigms in the field of Islamic art and architecture, often fragmented along linguistic, geographical, and national lines, or based on universalizing generalizations about unchanging Islamic "essences," have proved inadequate in dealing with the complex dynamics of visual culture in the Islamic lands.

Besides pointing out the inadequacies of existing paradigms that have accomodated misconceptions about the arabesque, in this study of the *girih* mode I have stressed the advantages of a semiotic framework in mediating the bipolar categories of "meaningful" versus "decorative," derived from the mimetic tradition of Western figural art. Just as there was no single universally accepted symbolic meaning for the *girih,* a total absence of meaning simply would have been unlikely. The polysemy of the *girih* mode, and of other abstract visual sign systems like it, made the signification process dependent on context and privileged subjectivity. The focus on geometry, abstract patterns, and calligraphy elevated them to the level of potentially meaningful forms around which various groups or individuals could develop their own systems of associations. Far from embodying an imagined horror vacui of the Islamic psyche, then, the covering of surfaces with variegated abstract patterns reflected a desire to create densely charged semiotic environments.

In the Islamic visual regimes more choices of interpretation were left to the viewer than in the figural narratives and iconographically codified representational symbols of the Christian world. Yet, as we have seen, additional pointers such as inscriptions often could guide visual contemplation in particular directions that were not always completely open-ended. Nevertheless, the very abstraction of Islamic visual signs made them adaptable to a wide variety of settings, profane and religious, including non-Muslim ones. The enthusiastic adoption of two-dimensional geometric interlaces, vegetal arabesques, muqarnas vaults (such as those in Norman Sicily, Byzantine Constantinople, Mudejar Spain, and the Armenian monuments of Anatolia) and of pseudo-Arabic inscriptions outside the Muslim lands shows that these highly flexible signs were always open to being interpreted as "decorative," "luxurious," or "exotic." The receptiveness to Islamic abstract patterns in the Latin West and Byzantium testifies to the shared aesthetic sensibilities highlighted throughout this book and underlines a certain fluidity of medieval intercultural boundaries despite religious differences.[144] Studying the visual cultures of the medieval European, Byzantine, and Islamic worlds as if they were unconnected blocks, therefore, only impoverishes our understanding of their distinctiveness.

The *girih* mode, which I have analyzed in terms of the ideological, intellectual, and aesthetic discourses that surrounded it, was one of the canonical visual idioms that dominated the Islamic lands during the early (950–1250) and late (1250–1500) middle periods. Future research with written sources, accompanied by new archaeological evidence, will no doubt further clarify the nuances of these discourses whose general outlines I have only sketched. A more systematic reading of juridical, theological, mystical, scientific, philosophical, and literary sources will continue to yield valuable insights capable of filling the gap created by the paucity of theoretical treatises on architecture and the arts.

Like the other modes of abstract patterning that accompanied it, the familiar decorative skin of the *girih* served to transform the surfaces of buildings and a wide variety of objects, without being restricted to any specific medium. It simultaneously provided an overall sense of visual unity to the *dār al-Islām* and highlighted the vigorous diversity within that world, which never constituted a homogeneous, monolithic bloc. It was this inherent duality of abstract sign systems—both linked to roots in a commonly shared Islamic past

and at the same time deviating from them through distinctive transformations—that assured their rich communicative potential. These polyvalent visual signs embodied both an overall familial resemblance and a studied individuality that served to articulate identity and difference. It was this intentional double edge, encouraging subtle internal visual dialogues within the Muslim world, that assured the long life of the *girih* mode.

NOTES TO PART 5

1. Edna St. Vincent Millay, sonnet 22 in *The Harp-Weaver, and Other Poems* (New York: Harper & Bros., 1923).

2. Kahwaji 1971. The concept of taste is discussed in Rahman 1965: "In aesthetics, *dhawk* is the name for the power of aesthetic appreciation; it is something that 'moves the heart.' But although it is psychologically subjective, it nevertheless requires objective standards *(idjmāᶜ)* for objectivity and verification."

3. For some examples of writing on music, see d'Erlanger 1930–1934; al-Kātib 1972; Ikhwān al-Ṣafā' 1978; and Ibn ᶜAbd Rabbih 1942. For a tenth-century treatise on calligraphy, see al-Tawḥīdī 1948. On calligraphy, see also al-Qalqashandī 1938, 41–45; al-Rāwandī 1957–1960, 2: 403–11; and Taşköprizāde 1895, 130–36. Biographical treatises on calligraphers and painters appear in the post-Timurid period with the rising prestige of the arts of the book. Some examples are translated in Thackston 1989, 335–50, 353–56. See also ᶜĀlī 1926; Sadiqi Bek's *Qānūn al-ṣuwar* in Dickson and Welch 1981, 1: 259–70; and Qāżī Aḥmad 1959. The only known biographical treatises on architects are from the Ottoman period; see Sāᶜī 1989; and Caᶜfer Efendi 1987.

4. For medieval Europe, see de Bruyne 1946; and Eco 1986, 93.

5. Clinton 1979, 81, 92–93. For Sururi's work (which is a synthesis of earlier Arabic, Persian, and Turkish manuals on prosody) written in 1549 for the Ottoman prince Mustafa, see Musliḥ al-Dīn Muṣṭafā Surūrī, *Baḥr el-maᶜārif* (Sea of knowledge), MS H. 659, fol. 5v, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul. For craft metaphors, see also Meisami 1987, 316–37.

6. Among the rare exceptions are Ettinghausen 1947; and Soucek 1972.

7. For the Brethren's popular audience, see Ibn al-Haytham 1989, 2: 100. The availability of the *Rasā'il* to such scholars as Ibn Sina, al-Ghazali, and Ibn Taymiyya and the background, identity, and philosophy of the Brethren of Purity is discussed in Kraemer 1986, 165–78. See also Fakhry 1983, 163–81.

8. Fakhry 1983, 166–67. For the Brethren's number theory, in which the number one is associated with the concept of *tawḥīd,* see Goldstein 1964.

9. Fakhry 1983, 169–80. For theories of emanation by al-Farabi, Ibn Sina, and Ibn Rushd and their impact on later Muslim and non-Muslim scholars, see Davidson 1992.

10. The quote is from Ikhwān al-Ṣafā' 1978, 35–36. For the epistle on music, see epistle 5 in idem 1928, 1: 132–80.

11. Ikhwān al-Ṣafā' 1978, 65–68. The Brethren's epistle on love and beauty is translated in idem 1975, 257–96.

12. For love and beauty, see Plotinus 1956, esp. pp. 57–59, 149. Ibn Sina's discussion of ideal beauty as an object of love is in the metaphysical section of the *Kitāb al-Shifā'* (Book of healing [of the soul]); see Ibn Sīnā 1978–1985, 2: 106–7. See also Ibn Ḥazm 1953, 28. The theme of love is also encountered in the Andalusian writer and poet Ibn ᶜAbd Rabbih's (860–940) *ᶜIqd al-farīd* (The unique necklace), whose section on music discusses the inexpressibility of musical beauty in words and its ability to arouse love in the soul: "When it appears, the soul falls in love with it and the spirit sighs for it. And for that reason Plato says one part of the soul should not be prevented from loving another"; see Ibn ᶜAbd Rabbih 1942, 7.

13. Ikhwān al-Ṣafā' 1978, 68.

14. Ibid., 7.

15. See epistle 6 in Ikhwān al-Ṣafā' 1928, 1: 181–94; and idem 1978, 26–27, 49–50.

16. Ikhwān al-Ṣafā' 1978, 49–50.

17. Ibid., 69.

18. Ibid., 49–51.

19. al-Rāwandī 1957–1960, 2: 403–11; al-Qalqashandī 1938, 3: 41–45; Taşköprizāde 1895, 130–36. See also Sabra's commentary on the proportioned script in Ibn al-Haytham 1989, 2: 99.

20. See al-Tawḥīdī 1948, where this saying is repeated on pp. 6 and 15. Al-Tawhidi's acquaintance with the Brethren is discussed in Kraemer 1986, 165–68. For ninth- and tenth-century mathematical treatises on ratio and proportion, see part 4, n. 129, above.

21. Translated in Abu Deeb 1979, 282.

22. For Sabra's enlightening discussion of the concept of proportion in medieval Islamic sources, see Ibn al-Haytham 1989, 2: 99–101.

23. Ibid., 2: 97.

24. Ibid., 1: 138–207.

25. Ibid., 1: 205.

26. Ibid., 1: 205.

27. Ibid., 1: 201.

28. Ibid., 1: 139, 200, 203.

29. See the *Philebus* in Plato 1961, 1132–33, where Socrates says: "The beauty of figures which I am now trying to indicate is not what most people would understand as such, not the beauty of a living creature or a picture; what I mean, what the argument points to, is something straight or round, and the surfaces of solids which a lathe or a carpenter's rule and square, produces from the straight and the round. . . . Things like that I maintain, are beautiful not, like most things, in a relative sense; they are always beautiful in their very nature, and they carry pleasures peculiar to themselves which are quite unlike the pleasures of scratching. And there are colors too which have this characteristic."

30. Ikhwān al-Ṣafā' 1978, 57.

31. Ikhwān al-Ṣafā' 1928, 1: 42.

32. Ibn al-Nadīm 1970, 2: 608.

33. Proclus 1970, 29.

34. Ibid., 4.

35. Ibid., 18.

36. Ibid., 38, 87. Referring to the three ways of "moving upward" as outlined in the *Phaedrus* of Plato, Proclus noted that just as the senses of sight and hearing used beautiful objects and harmonious sounds as intermediaries in their upward journey, the philosophic nature turned to mathematical forms as stepping stones toward intellectual understanding; see idem, 18.

37. Ibn Khaldūn 1967, 2: 130–31. For the full quote, see part 3, pp. 103–4, in the present volume.

38. Ibn Sīnā 1978–1985, 1: 98.

39. Translated in Cantarino 1975, 147.

40. For al-Ghazali, see Fakhry 1983, 217–32; and Davidson 1992, 127–80. For Ibn Sina's influence on Aquinas and the prohibition of his works in Europe, see Goichon 1971.

41. Cited in Ettinghausen 1947, 165.

42. Ibid. Grabar defined ornament as a relationship of love in *The Mediation of Ornament,* where he quoted Plato's discussion on love in the *Symposium:* "Ornament is itself or exhibits most forcefully an intermediate order between viewers and users of art, perhaps even creators of art, and works of art"; see Oleg Grabar 1992, 45.

43. Cited in Ettinghausen 1947, 162.

44. Ibid., 164.

45. Ibn Khaldūn 1967, 2: 397–98.

46. Translation mine; see Taşköprizāde 1895, 405–6.

47. al-Dawwānī 1839, 32. For the inscription, see part 5, n. 37, above.

48. Ibid., 117–26.

49. See "Plotin et les origines de l'esthétique médiévale," in André Grabar 1992, 29–87. For a recent critique and revision of Grabar's article, see Gurtler 1989. For Byzantine aesthetics, see also Mathew 1963.

50. Augustine 1950, chaps. 8–11.

51. For Augustine's theory of beauty, see Barasch 1985, 60–63.

52. For Boethius, see de Bruyne 1946, 1: 3–34.

53. For Grosseteste, see part 4, n. 91, above; de Bruyne 1946, 3: 134–35; and Crombie 1953. Theories of light and vision are discussed in Sabra 1967; Lindberg 1967; idem 1976; and the chapter "The Aesthetics of Light," in Eco 1986, 43–51.

54. For the aesthetics of Aquinas, see de Bruyne 1946, 3: 317–28; Barasch 1985, 97–101; and Thomas Aquinas 1970.

55. Cited in Panofsky 1946, 63, 65. See also Kostof 1985, 325: "Proportional schemes are of course a function of geometry, and geometry was, like music, an 'anagogical'

activity—that is, it had the ability to lead the mind from the world of appearances to the contemplation of the divine order. It is not surprising that so much attention should be paid to geometric proportions in later medieval architecture, and that even in its wildest expressive fury Romanesque sculpture should follow in its structure and composition a firm regimen of geometry." For a critique of Panofsky's interpretation of Suger, see Kidson 1987.

56. Eco 1986, 15.

57. Ibid., 16. For the "analogical mode of thought" in medieval Persian poetics, see Meisami 1987, 30–39.

58. Plotinus 1956, 58. For Boethius, see de Bruyne 1946, 1: 26–32. A survey of classical and medieval theories of imagination is undertaken in Bundy 1927; and the chapter "Naissance d'images," in Vernant 1979, 105–37.

59. For the relationship between artistic creativity and dream inspirations, see Meier 1966, 423. The relationship among dreams, imagination, and the imaginal realm is discussed in Rahman 1966.

60. al-Tawḥīdī 1948, 9. Seneca wrote that the writer should follow the example of the bee, who gathers nectar from the flowers and breathing into it makes honey; cited in Summers 1987, 120.

61. Sāʿī 1989, 52–56, 140–42, 172, 118–19, fols. 2b–3a, 14b. The sixteenth-century Ottoman writer Eyyubi described Sinan's inspired talent in similar terms, referring to his God-given power of sanctity by which miracles are worked (*kerāmet*) and to his advanced spiritual states: "Aña virmiş ḫüdāsı çoḳ kerāmet / Ḳomış ṣadrında anuñ özge ḥālāt" (God has given him much power of sanctity / Placing in his heart special spiritual states). He praised Sinan as the "philosopher of the age" (*zamāne feylesofı*) to whom Aristotle would have become a disciple; see Eyyūbī 1991, 190. For Evliya Çelebi's references to miraculous saintly powers in artistic creation, see part 4, n. 132, above.

62. Ibn Sīnā 1968, 14–15; idem 1963, 14; Ibn Khaldūn 1967, 2: 347. For the Brethren, see Wolfson 1935, 77. Ibn Sina is also discussed in Kemal 1991, 142–43.

63. Wolfson 1935.

64. Mahdi 1980, 45–46.

65. Summers 1987, esp. pp. 262–63; Wolfson 1935, 114–31. For Aquinas's discussion of the internal senses, see de Bruyne 1946, 3: 317–28.

66. Summers 1987, 204.

67. Ibn Khaldūn 1967, 2: 347.

68. Wolfson 1935, 69–95. For al-Kindi's discussion of the internal senses, see Fakhry 1983, 86–88.

69. For the Brethren's discussion of the internal senses, see Ikhwān al-Ṣafā' 1975, 187–208. For their definition of "making," see idem, 519. The same definition appears in epistle 8 in idem 1928, 1: 211, 218. For the loftiness of the crafts, see idem 1975, 6–7; and epistle 8 in idem 1928, 1: 219–21. Not all crafts were considered honorable in Islam; their hierarchy is discussed in Brunschvig 1962.

70. Ibn Sīnā 1978–1985, 1: 98.

71. Wolfson 1935, 69–133; Davidson 1992, 89–123.

72. Wolfson 1935, 95–102. For Ibn Sina's theory of the internal senses, see Gätje 1965; Fakhry 1983, 139–44; and Ibn Sīnā 1952, 30–40. Al-Farabi's and Ibn Sina's theories of imagination are explained in Kemal 1991, 89–169.

73. For al-Ghazali's classification of the inner senses, see Fakhry 1983, 248–49; Davidson 1992, 127–44; and Wolfson 1935, 101–4.

74. Cited from the *Kimyā-i saʿādat* (Chemistry of happiness) in Ettinghausen 1947, 163.

75. Cited in ibid., 163.

76. Cited in ibid., 164–65.

77. For a translation of Ibn al-Haytham's *Kitāb al-manāẓir*, see Ibn al-Haytham 1989; this source is also discussed in Sabra 1978; idem 1987a; and idem 1989. For the observatory in Islam, see Sayılı 1960.

78. Ibn al-Haytham 1989, 1: 128.

79. Ibid., 1: 130.

80. Ibid., 1: 208–9, 223.

81. Ibid., 1: 129, 222.

82. Ibid., 1: 208.

83. Ibid., 1: 206.

84. Ibid., 1: 274–75.

85. Cited in Grabar 1978, 144, and published in Goury and Jones 1842–1845. For the Arabic inscriptions of the Alhambra and their Spanish translations, see García Gómez 1985.

86. For the term *imʿān-i naẓar*, see Evliyā Çelebi, *Seyāḥatnāme*, vol. 2, MS B. 304, fols. 221r, 246r, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul; and idem vol. 3, MS B. 305, fol. 47v, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul.

87. Translated in Kraemer 1986, 163.

88. Translated in Abu Deeb 1979, 264–65. For the frequent connection between art and magic in premodern Islamic texts, see Bürgel 1988; and part 4, n. 132, above.

89. Soucek 1972, 11–19.

90. The passages from Khwandamir are translated in Thackston 1989, 205, 224. The eulogy of Ahmad Lahori is cited from the collection of poems by his son Lutf Allah, in Begley and Desai 1989, 267. See also Evliyā Çelebi, *Seyāḥatnāme*, vol. 1, MS B. 304, fol. 118r, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul; idem vol. 2, MS B. 304, fol. 224v, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul; and idem vol. 4, MS B. 305, fols. 314v–315, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul.

91. Translated in Thackston 1989, 353, 355.

92. Translated in Dickson and Welch 1981, 1: 259–70.

93. Translated in ibid., 1: 260.

94. Translated in ibid., 1: 264–65. For poetic imitation, see Meisami 1987, 307–12.

95. Clinton 1979, 81, 92–93.

96. For the science of metrics, see Weil and Meredith-Owens 1960; and Elwell-Sutton 1987. The ideal forms of the five circles were called *buḥūr* (from *baḥr*, lit., "river"). In his prosody manual written in 1549, Sururi drew six circles and referred to nineteen fundamental meters, the last three of which are generally described as Persian meters that were added to the traditional sixteen Arabic ones. He said that the fundamental meters (*buḥūr-i aṣlīye*) generated many variants, thirty-four of which were famous among Persian poets; see Surūrī, *Baḥr el-maʿārif*, MS H. 659, fols. 6r–18r, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul. Ibn Khaldūn 1967, 3: 375–76.

97. Ibn Khaldūn 1967, 3: 379.

98. Ibid., 3: 342, 2: 346, 354–55.

99. Ibn Sina is cited in Fakhry 1983, 140–41; and Niẓāmī ʿArūẓī 1978, 32. Nizami ʿAruzi referred to artistic imagination (*khiyāl*) as "a faculty located in the posterior portion of the anterior ventricle of the brain, which preserves what the 'Composite [or Common] Sense' (*ḥiss-i mushtarak*) has apprehended from the external senses, so that it remains in it after the subsistence of the sense-impressions"; see idem, 8–12.

100. See al-Farabi's treatise on music, translated into French in d'Erlanger 1930–1934, 1: 23–24. For the concept of *maqām* and related bibliography, see Powers 1980.

101. d'Erlanger 1930–1934, 1: 8–13, 30.

102. Ibid., 1: 39.

103. Ibid., 2: 40–48. For craft analogies in Persian poetics, see Meisami 1987, 316–37; and Clinton 1979.

104. Goury and Jones 1842–1845, commentary on pl. 10.

105. Wright 1993. Caʿfer Efendi correlated the twelve principal modes (*maqām*) of seventeenth-century Ottoman music with the twelve signs of the zodiac and their various derivatives with the four elements, the seven planets, and the twenty-four hours of the day; see Caʿfer Efendi 1987, 26–27.

106. Ibn Sīnā 1952, 38. For Ibn Sina's theory of the hierarchical grades of abstraction, see idem, 33–56; and idem 1968, 27–28, 46–48, 52–53. Sana'i is quoted in Meisami 1987, 303–4.

107. For the Renaissance perspectivalism and the Baroque vision, see Jay 1988.

108. Cheetham 1991.

109. For Matisse's fascination with the Islamic decorative arts, see Bois 1993. For Fauvism and the arabesque, see Benjamin 1993. The so-called Turkish painter's man-

ual is cited in Cheetham 1991, 5, 19; and in Herbert 1958, 151 n. 21, where it is described as follows: "The copy, in Seurat's hand, is in the Signac Archives. Mme Cachin-Signac has established the fact that the original source is a manuscript by the Turkish poet Vehbi Mohamed Zunbul-Zadé [i.e., Vehbi Sünbülzade] (died 1809)." Although Herbert suggested that this text must have been based on an Ottoman original composed by Sünbülzade, Cheetham believed that it was an apochryphal text written by Gauguin himself; see Cheetham 1991, 5. I have not been able to locate Sünbülzade's original text to determine the degree to which Gauguin made use of it. Extensive quotations from the "Turkish painter's manual" were published in Gauguin's *Avant et après;* see Gauguin 1923, 55–59. These excerpts suggest that Gauguin probably elaborated upon an original Ottoman text that may well be discovered one day. The manual recommends the use of primary colors and deliberate ornamentation to efface the realism of represented objects in order to move the heart of connoisseurs with a sense of beauty. For Sünbülzade's literary works, see Köprülü 1966, 17–72, 197, 208, 215–16, 306, 403; and Beyzadeoğlu 1993. The "Turkish painter's manual" is not listed among his known works.

110. Hodgson 1974, 2: 506. Dost-Muhammad's preface and Dughlat's *Tā'rīkh-i Rashīdī* (History of Rashid) are translated in Thackston 1989, 336, 349, 361–62. See also Dūghlāt 1895.

111. For biographies of painters and calligraphers, see part 5, n. 3, above. The petition is translated in Thackston 1989, 332.

112. Translated in Cantarino 1975, 91–92. Ibn Sina wrote, "The kind of objective truthfulness in poetry is ugly from the standpoint of the art and what is necessary for it"; see idem, 218.

113. Translated in ibid., 218–20.

114. For example, al-Jurjani clearly expressed a preference for artificiality by declaring that "the best poetry is that which lies most"; see ibid., 164.

115. For the role of wonder, see Kemal 1991, 154–69.

116. See ibid., 161–62: "In the case of poetic utterances, pleasurable awe is our response to the meaningful harmony in their composition, and we must see it as a qualitatively distinct experience even if it has parallels with and eventually may even depend on demonstrative certainty."

117. Gibb 1958–1967, 1: 127–29, 2: 11–13; Rypka 1968, 281–82.

118. Subtelny 1986. According to Gibb, imitational monorhyme poems were known as *naẓīra,* or parallel, and poems written in emulation of longer works were called *jewāb,* or response. He observed that the fascination with imitational poetry "lay in the endeavour to outdo one's fellow-craftsman on his own chosen ground"; see Gibb 1958–1967, 1: 99–100.

119. I am grateful to Paul Losensky for sending me the chapters on Timurid-Turkmen and Safavid-Mughal poetry from his Ph.D. dissertation at the University of Chicago. See Losensky 1993. The tendencies in the visual arts highlighted by Losensky are discussed in Lentz and Lowry 1989.

120. Lentz and Lowry 1989, 221, 204.

121. Quoted in Subtelny 1986, 57–58. See also Dawlatshāh al-Samarqandī 1901.

122. Subtelny 1986, 59.

123. For the inscription, see Notkin 1995. This inscription is transliterated and translated in part 1, n. 124, above. The relationship between poetic enigmas and the Timurid visual arts is discussed in Lentz and Lowry 1989, 284–85.

124. From the viewpoint of the psychology of aesthetic perception outlined in Muslim sources, the question that Golombek and Wilber asked about whether Timurid audiences would have understood geometric harmonization becomes irrelevant: "But could the fifteenth-century person, even of raised consciousness, distinguish a geometrically proportioned space from one that was not? Alas, the question cannot be answered! . . . To what extent the average visitor was sensitive to the geometric harmonization of the building is impossible to gauge. There were probably enough clues, however, in the surface decoration and vaulting, to suggest deeper geometric involvement and to lead him to the conclusion that the entire work had been proportionally conceived. It matters not, therefore, whether the total harmonization can be perceived in the final product. It is sufficient that the observer believe the principles of harmonization had been followed at the stage of conception"; see Golombek and Wilber 1988, 1: 211–12. This passage assumes that visual communication had to be a conscious process, whereas the medieval Islamic texts we have considered suggest that an unconscious, mysterious emotional quality was at work that transcended expression in words. No wonder, then, that descriptions of objects or buildings rarely attempted to linguistically articulate what constituted the basis of visual beauty. Instead they tended to express wonder and amazement, usually followed by remarks about the inexpressibility of aesthetic experience.

125. Lentz and Lowry 1989, 210.

126. For Nawa'i's restoration of the Great Mosque of Herat, see O'Kane 1984, 70–72.

127. For the cultural ethos of the early modern age, see Necipoğlu 1993a. The theme of desacralization in the early modern Ottoman world is treated in Kafadar forthcoming.

128. Losensky 1993. The earliest examples of *sabk-i Hindī* poetry were composed by the Persian poet ʿUrfi of Shiraz (1555–1590), who moved to India, and by his associate Fayzi.

129. Gibb 1958–1967, 1: 129–30. The new style of poetry emerged in the late classical age of the Ottoman empire, enjoying popularity during the seventeenth and early eighteenth centuries among such poets as Nefʿi and Nabi. For the reception of the *sabk-i Hindī* in the Ottoman context, see Nābī 1994, 205–57.

130. Losensky 1993.

131. Translated in Dickson and Welch 1981, 1: 264.

132. Translation mine. Cited from Sünbülzade in Beyzadeoğlu 1993, 53: "Īʿtibār eyleme hendeseye / Düşme ol dā'ire-i vesveseye." For the term *visual regime,* see Foster 1988, ix–xiv.

133. See Necipoğlu 1990b; and idem 1992a.

134. Kanbu is cited in Riazul Islam 1970, 171.

135. Translated in Begley and Desai 1989, 82–83.

136. See Koch 1991; Asher 1992; and Welch 1985.

137. Cited from the Mamluk writer al-Samhudi's (1440–1506) history of Medina in Creswell 1932–1940, 1: 149.

138. Muqaddasi is cited in ibid., 1: 66.

139. Ibn Khaldūn 1967, 2: 286–87, 302, 347–52.

140. Ibid., 1: 347, 351–58; 2: 235–39, 351–463.

141. Ibid., 2: 430–31.

142. Taʿlīḳīzāde Meḥmed Ṣubḥī Çelebi b. Muḥammed el-Fenārī, *Tebrīzīye,* MS R. 1299, fol. 38, Topkapı Sarayı Müzesi Kütüphanesi, Istanbul.

143. For an outline of shifting paradigms in palace architecture, correlated with dominant political configurations, see Necipoğlu 1993b.

144. For a methodological discussion of the question of intercultural exchange in Muslim and Christian frontier societies and the fluidity of cultural identities in late medieval Anatolia, see Kafadar 1995.

CATALOG: PATTERN TYPES AND DRAWINGS IN THE TOPKAPI SCROLL

LIST OF PATTERN TYPES

The two- and three-dimensional drawings of the Topkapı scroll were generated by underlying geometric grid systems consisting of inked construction lines or uninked, incised lines. Based on a limited vocabulary of geometric shapes transformed by the symmetry operations of translation, reflection, glide reflection, and rotation, these complex drawings exemplify the role of a formal grammar in structuring design thinking. Specific points on the construction lines were connected to generate a final pattern or to create a secondary grid network that could be further subdivided into a multilayered design. In these drawings weblike linear crossings, or knots, often form star centers with *n*-fold rotational symmetry, surrounded by polygons, star polygons, and their fragments. Points around which design elements are radially organized are often complemented by vertical, horizontal, diagonal, and oblique axes of symmetry along which elements are repeated or reflected. Complex patterns with shifting rhythms are sometimes stabilized by highlighting certain elements with color, or by emphasizing some lines and erasing others. At times the generating grid lines constitute an integral part of the final pattern, but more often they act as underlying uninked "dead" construction lines that structure the pattern.

The drawings of the Topkapı scroll can be classified in terms of distinct pattern types whose shared characteristics are summarized below. It is, of course, possible to provide a more precise mathematical classification based on the underlying symmetrical properties of each drawing. Such a classification using the scientific language of symmetry notation developed by group theory and crystallography, however, falls beyond the purview of this book. The following classification constitutes a descriptive catalog of the Topkapı scroll's contents, not a rigorous scientific analysis of each pattern. The catalog of pattern types is followed by a list of individual drawings with brief descriptions explaining the possible functions and grid systems of each pattern and providing guidelines for future analysis.

Group I: Two-Dimensional Patterns Generated by Squared Grids (cat. nos. 1, 37, 40, 43, 45, 47, 51, 65, 68b, 69a, 72a, 74–77, calligraphic details of cat. nos. 38, 41)

Drawings belonging to this group are two-dimensional calligraphic and geometric patterns, or a combination of the two. They were intended mainly for *bannā'ī* brick masonry, although they could also be applied to other media such as carved or painted plaster, stone carving, woodwork, and mosaic tile work. Their squared grids, corresponding to modular glazed or unglazed brick shapes used in *bannā'ī* masonry, facilitated the task of masons in laying out patterned bricks of standard shapes in 45, 90, and 135 degrees. Repeat patterns of this type were commonly used in the exteriors of Timurid-Turkmen monuments and in their courtyard facades covered with revetments in the *bannā'ī* technique. These bold patterns, easily read from a distance, were usually

accompanied by more intricate, minutely rendered curvilinear designs and cursive inscriptions in mosaic or *cuerda seca* tile work. Used sparingly, the latter rarely counterbalanced the rigid angularity of geometric *bannā'ī* brick masonry patterns so dominant in the exterior revetments of Timurid-Turkmen monuments.

Most drawings generated by squared grids in the Topkapı scroll consist of square panels in which both the grid network and the pattern generated by it are rendered in black-ink lines (cat. nos. 1, 37, 43, 45, 47, 51b, 51f–h, 65, 76). Some drawings in this group, however, are drawn in red or orange ink over a checkered black grid in order to separate the final pattern from its underlying grid (cat. nos. 51e, 51i, 68b, 69a). More complicated composite calligraphic designs are executed in several colors that indicate the symmetrical distribution of different fields of glazed bricks in varied colors. Some use black and red, or black and orange (cat. nos. 75, 77), others a combination of orange, yellow, and green, with black lettering (cat. no. 74).

Most of these square panels display rotational symmetry; their patterns revolve around a fixed center forming an eight-pointed star, square, cross, or swastika at the middle of the square frame (cat. nos. 1, 37, 43, 47, 51b, 51i, 69a, 74–77). Those that are asymmetrical consist of square kufic calligraphy meant to be read in a counter-clockwise direction (cat. nos. 45, 51h, 65, 68b). The remaining drawings generated by squared grids are contained in rectangular frames that form either self-contained panels or strips of linear repeat units, often possessing bilateral symmetry, meant to be extended in two directions (cat. nos. 37, 40, 51a, 51c–g, 72a). They, too, are color coded or simply drawn in black ink, depending on their relative complexity. Patterns belonging to this group include the calligraphic details of cat. nos. 38 and 41 contained in rotated square- and rhombus-shaped compartments whose grids are composed of squares or rhombuses drawn in black ink.

The Topkapı scroll's geometric designs generated by checkered grids are all standard repeat patterns dominated by squares, octagons, star octagons, and their fragments, most of which have pre-Timurid precedents and also appear after the Timurid period. The scroll's calligraphic patterns consist of relatively common pious phrases or the symmetrically repeated names *Allāh*, *ʿAlī*, and *Muḥammad*. Except for one hadith inscription in the naskhi script adapted to the *bannā'ī* technique (cat. no. 51a), and a partial Koranic one (cat. no. 74), none of the square kufic designs consists of long sentences or full quotations from the Koran. More extensive inscriptions, often rendered in the cursive scripts, were generally designed by the professional calligraphers of court scriptoria (*kitābkhāna* or *kutubkhāna*) according to the specific epigraphic programs of individual monuments. They are therefore absent in the Topkapı scroll, which does not include curvilinear motifs drawn by painter-designers.

The square kufic inscriptions of the Topkapı scroll are standard phrases that include the ninety-nine names of God and well-known Arabic pious aphorisms such as the Muslim professions of faith "There is no God but God and Muhammad is his Prophet," "Muhammad is the Prophet of God," "Praise be to God," "God is Great," "Sovereignty is God's," "Generosity is God's," and "Authority is God's," occasionally accompanied by Persian phrases such as "May He be Blessed." Contained in framed panels, such inscriptions—most of them easily legible but some requiring a greater effort to decode—became a trademark of Timurid-Turkmen monumental epigraphy. They provided a calligraphic analogue to the geometric compositions that often accompanied them, both generated by squared grids related to standard brick shapes.

Group II: Two-Dimensional Patterns Generated by Triangulated Grids (cat. nos. 71, 91)

Only two drawings in the Topkapı scroll were generated by isometric grids composed of equilateral triangles in contact, drawn in black ink. Both of them depict hexagonal calligraphic medallions with rotational symmetry. Such triangulated grids (with multiples of 60-degree angles that give the designer control over horizontal and diagonal rhythms) were commonly used in generating geometric patterns based on the hexagon and

its derivatives. They are dominated in the Topkapı scroll by squared grids with patterns forming 45-, 90-, and 135-degree angles better suited to the standardized brick shapes of *bannā'ī* masonry.

Group III: Two-Dimensional Star-and-Polygon Patterns Generated by Composite Radial Grids (cat. nos. 4a, 8, 10b, 28–36, 38, 39, 41, 42, 44, 46, 48–50, 52–64, 66, 67, 68a, 69b, 70, 72b–d, 73, 81a, 90a, 105, 114)

These patterns were generated by subdividing with equidistant radii the circumferences and arcs of composite systems of concentric circles, distributed at congruent intervals on an infinitely extendable plane and often cut by horizontal, vertical, diagonal, and oblique axes of dynamic symmetry. Prolonging the points or radii of stars generated by such uninked radial grids in straight lines until they meet creates interlocking polygons, star polygons, and their fragments, displaying a high degree of symmetry. The largest stars in each pattern form *n*-fold rotational symmetry, with the smaller peripheral stars revolving around them possessing lesser degrees of rotational symmetry, so that the plane as a whole is studded with roto-centers of differing intensities.

The composition of star-and-polygon patterns interlocking in an infinite variety of angles, therefore, involves a search for permutations of possible arrangements of star centers in a plane. The number of possibilities is limited by the precise way in which each star center has to be related to its surrounding neighbors, since the correct relative sizes of congruent tilings of multiple star motifs follow fixed geometric rules. The wide variety of repeat units for such patterns included in the Topkapı scroll reveals that its designers were well versed in these underlying geometric rules that they skillfully manipulated.

Not every pattern was suitable for the differently proportioned panels that fragment the surfaces of Timurid-Turkmen monuments. The square or rectangular frames of revetment panels composed of star centers distributed at regular intervals corresponded to certain proportional relationships. Generally each corner of such quadrangular panels was occupied by a quarter star, but some of them also featured half stars along their sides. Square panels were dominated by patterns with four-, eight-, or twelve-sided stars and polygons forming 45-, 90-, and 135-degree angles. Repeat units with hexagonal stars and polygons were suitable for rectangular panels whose diagonals formed a 60-degree angle with the base. Panels composed of five- and ten-pointed stars interlocking with pentagons and decagons, however, were based on rectangular repeat units whose diagonal formed an angle of 36 degrees. This explains why so many variants of similar star-and-polygon patterns contained in differently proportioned quadrangular repeat units are included in the Topkapı scroll. The scroll also has some examples of star-and-polygon patterns in rectangular or square frames adapted to the curved profiles of arched panels (cat. nos. 35, 39, 105) as well as triangular or kite-shaped designs (cat. nos. 4a, 10b, 90a) for the curved surfaces of vaults.

With a practical knowledge of the angular properties of polygons and star polygons generated by uninked radial grid systems oriented along axes of dynamic symmetry, a pattern could be found to suit a revetment panel of almost any proportion. The two-dimensional star-and-polygon patterns of the Topkapı scroll were primarily intended for mosaic tiles and the inset technique (using plaques made of mosaic or *cuerda seca* tile work). The inset technique allowed the designer to accentuate some geometric compartments with plaques bearing curvilinear vegetal motifs or rosettes. A few star-and-polygon patterns in the scroll feature thick outlines (cat. nos. 50, 53, 57, 61) that would have been translated into mosaic tile work as separate bands outlined by parallel lines, unlike the majority of patterns with thin lines indicating contiguous borders of interlocking forms. Star-and-polygon patterns were also commonly used in Timurid-Turkmen carved or painted plasterwork, largely confined to interiors, and less frequently in stone carving and woodwork.

(III. i.) Patterns with Dotted or Solid Grid Lines (cat. nos. 4a, 28, 29, 31–34, 44, 48, 50, 52–64, 72c–d, 90a)

A large number of star-and-polygon patterns in the Topkapı scroll are provided with underlying

dotted or color-coded solid grid lines, defining polygons in contact or stars interlocking with polygons. These grids are accentuated with red- or black-dotted lines, with the black dots gone over in solid orange or with solid orange and red lines, so that they clearly stand out from the final star-and-polygon pattern drawn in black ink. In one example (cat. no. 4a) only a black-dotted grid of polygons in contact is shown, without providing the final pattern generated by it. This group can be divided into three subsets:

(III.i.a.) Grids with Stars and Polygons in Contact (cat. nos. 28, 29, 31, 32, 34)

In these examples some points of grid lines represented by black dots gone over in solid orange coincide with the centers of stars or polygons drawn in smaller scale in black ink. The orange grids that delineate stars and polygons in contact, then, determine the congruent distribution of smaller star centers within each repeat unit. These grids often consist of quarter stars that occupy one or two diagonal corners of a repeat unit (cat. nos. 28, 29, 31, 32, 34); some of them also feature half stars along the edges (cat. nos. 31, 34). Occasionally, uninked oblique axes of symmetry cut the repeat unit into congruent sections (cat. no. 34), determining the points where the centers of half stars and half polygons drawn in black ink fall along the edges of the outer frame.

It is the respective positioning of half stars along the sides and of quarter stars at the corners of repeat units that guides the composition of the orange grid lines that generate star-and-polygon patterns on a smaller scale drawn in black ink. These drawings, then, consist of two superimposed layers of proportionally related star-and-polygon patterns in different scales, the larger master grid highlighted in orange, and the smaller patterns generated by it outlined in black. The designer could either juxtapose the two systems of superimposed drawings in the final executed pattern or eliminate one of them. In one example (cat. no. 28) three layers of pattern are superimposed: a dotted grid of polygons in contact, an orange grid with stars and polygons in contact, and a black-ink star-and-polygon pattern generated by the first two grid systems.

(III.i.b.) Grids with Polygons in Contact (cat. nos. 28, 33, 44, 48, 50, 52–58, 60, 62–64, 72d, 90a)

In these examples dotted or solid grid lines in red that define polygons in contact generate interlocking stars and polygons by means of two crossing straight lines in black ink that bisect the sides of the polygonal grids. In several examples (cat. nos. 48, 53, 54, 56) some of the red-dotted grid lines are trisected by pairs of two crossing black-ink lines. The crossed lines that bisect or trisect the sides of dotted polygons in contact form similar angles; they are prolonged until they meet lines emanating from neighboring polygons.

In such drawings the points of smaller-scale star-and-polygon patterns rendered in black ink invariably fall onto the centers of the sides of the dotted polygons in which they are contained (the only exceptions are drawings with trisected grid lines). The repeat units of these polygonal grids feature different combinations of corner quarter stars and of lateral half stars. The most common combination consists of two quarter stars at adjacent corners and one half star situated in the middle of the opposite side (cat. nos. 33, 44, 56, 58, 60, 62–64). Another combination with two quarter stars at opposite diagonal corners results in more dynamic compositions involving diagonal and oblique axes of symmetry that cut the repeat unit into congruent sections (cat. nos. 50, 52–55, 57, 72d).

The polygonal grids that primarily served as guidelines for artisans were meant to be eliminated from the final executed pattern. These polygons in contact, which condensed uninked radial grid lines of concentric circles subdivided by equidistant radii into shorthand formulas, must have facilitated the transfer of complex patterns onto wall surfaces.

(III.i.c.) Grids Featuring Squares with Four Prolonged Sides (cat. nos. 59, 61, 72c)

This group of drawings is based on composite grids combining uninked radial networks and red-dotted small squares with four prolonged sides that proportionally cut the larger square repeat units containing them into congruent parts. These congruent parts consist of a central square surrounded either by four triangles or by four rectangles. Two of the examples belonging to this category (cat. nos. 61, 72c) have square repeat

units with a red-dotted smaller square of four prolonged sides in the middle (one of them rotated). The four points at which the prolonged sides of the inner square meet the framing outer square determine the centers of the quarter or half stars that generate the pattern drawn in black ink.

A third variant using this type of composite grid is the square repeat unit of a pattern symmetrically divided into four quarters, each containing a red-dotted rotated square of four prolonged sides (cat. no. 59). Once again the points at which the dotted lines intersect the framing outer square determine the centers of quarter and half stars generated by uninked radial grid lines. The four dotted lines intersecting at the middle of the composition define the center of yet another star with six points. The dotted grid lines were probably eliminated from the final pattern.

(III.ii.) Patterns without Dotted or Solid Grid Lines (cat. nos. 8, 10b, 30, 35, 36, 38, 39, 41, 42, 46, 49, 66, 67, 68a, 69b, 70, 72b, 73, 81a, 105, 114)
This group of star-and-polygon patterns does not feature dotted or solid grid lines. Its patterns are generated by uninked radial grids accompanied by uninked axes of dynamic symmetry. They are all drawn in black ink, with some elements highlighted in orange. The patterns are mostly contained in square or rectangular repeat units, with the exception of a slightly curved triangular pattern of a vault section (cat. no. 10b). This group can be divided into three subsets:

(III.ii.a.) Patterns Generated by Uninked Radial Grids Oriented along Axes of Dynamic Symmetry (cat. nos. 8, 10b, 30, 35, 36, 39, 42, 46, 66, 72b, 73, 81a, 105)
In most of the square and rectangular repeat units of this group star centers are determined by uninked vertical, horizontal, oblique, or diagonal axes of symmetry that intersect at the middle of the composition, proportionally cutting it into congruent parts. The points at which these uninked axis lines intersect the outer frame of each repeat unit define the centers of quarter and half stars or of other polygonal shapes generated by radial grid lines (cat. nos. 8, 30, 36, 39, 42, 46, 66, 72b, 73, 81a). These are complemented by star-and-polygon patterns adapted to arch profiles (cat. nos. 35, 39, 105) and to vault sections (cat. no. 10b).

(III.ii.b.) Patterns Generated by Composite Grids with Rotated Squares or Rhombuses Containing Swastikas (cat. nos. 41, 67, 68a, 69b, 70)
Star-and-polygon patterns that fall into this group are composed of composite radial grid systems with rotated squares or rhombuses containing swastikas. Their uninked underlying composite grids often feature subdivided squares or rhombuses that generate swastikas drawn in black ink.

(III.ii.c.) Double-Layered Patterns for Relief Mosaic Tile Work (cat. nos. 38, 49)
This group consists of rectangular repeat units for double-layered patterns in different scales, proportionally related to one another. They were generated by uninked composite grids composed of arcs and circles subdivided by equidistant radii and oriented along axes of dynamic symmetry. The smaller-scale star-and-polygon patterns in the background are superimposed with large foreground motifs of stars, polygons, and their fragments. These drawings were intended for relief mosaic tile panels in which the large foreground elements would have been slightly raised above the background. Their peculiar characteristic is that the raised foreground motifs would form a continuous field if joined together; moreover, their corners coincide with the centers of some large stars belonging to the intricate background pattern.

(III.iii.) Curvilinear Pattern (cat. no. 114)
Only one drawing, the last, in the Topkapı scroll is completely curvilinear. Its frame indicates that no other patterns followed it. Generated by uninked circles superimposed on an uninked orthogonal grid formed by horizontal, vertical, and diagonal lines, it is a curvilinear variant of angular star-and-polygon patterns drawn in black ink. Curved hexagons fill the spaces left in between each six-fold rosette.

Group IV: Three-Dimensional Star-and-Polygon Patterns for Vaults and Transitional Zones (cat. nos. 2, 3, 4b, 5–7, 9, 10a, 10c, 11–27, 78–80, 81b, 82–89, 90b, 92–104, 106–113, details of cat. nos. 2, 25)

These three-dimensional patterns consist of triangular, quadrangular, and kite-shaped repeat units

for vaults and vault sections. They range from relatively simple linear drawings of stellate arch-net and muqarnas vault projections with basic polygonal units, to more complex, color-coded and stippled designs for star-studded muqarnas vaults emanating from fan-shaped or shell-shaped hoods. They can be divided into two subsets:

(IV.i.) Stellate Arch-Net Vaults (cat. nos. 83c, 89a, 90b, 92a, 93, 94, 111b, details of cat. nos. 2, 25)

Vaults with intersecting arches forming nets that fill squinches and create stellate patterns around the bases of domes became widely used for the first time in Timurid-Turkmen architecture. The Topkapı scroll provides designs for arch-net vaults of various types, all of them generated by uninked radial grids consisting of one or more concentric circles or arcs divided into equal parts by shared radii that emanate from a single center. Their varied number of circles and radii result in different stellate configurations.

Besides square and rectangular repeat units of arch-net quarter and half vaults (cat. nos. 92a, 93, 94), the Topkapı scroll also provides examples of arch-net vault fragments that complement larger vault patterns (cat. nos. 2, 25, 83c, 89a, 90b, 111b). The latter were probably meant to be used in conjunction with the accompanying vault design, mostly in squinch corners or geometric compartments at the transitional zones of vaults. All patterns in this group are rendered in black-ink lines and their underlying radial grids are uninked. Occasionally some compartments are marked by stippled dots to code spatial properties (cat. nos. 93, 94).

(IV.ii.) Stellate Muqarnas Vaults

(IV.ii.a.) Fan-Shaped Radial Muqarnas Vaults (cat. nos. 4b, 5, 6, 11, 12, 13a, 14, 15a, 16, 17a–b, 18, 19b, 20–22, 24, 26, 78b, 79, 80, 82, 83a, 84, 85, 88, 92b, 98, 102, 106c, 107–110, 111a); Muqarnas Fragments (cat. nos. 9, 10a, 10c, 13b, 15b, 17c, 78a, 81b)

These drawings constitute the largest group in the Topkapı scroll. They include a wide variety of muqarnas quarter, half, and full vault patterns contained in square or rectangular frames, all of them emanating from fan-shaped stellate hoods. When quadrupled, the quarter repeat units would form muqarnas full vaults, and when doubled they created half vaults for arched portals, iwans, and nichelike recesses such as mihrabs. Not all of the repeat units for muqarnas quarter vaults, however, were meant for full vaults. The use of asymmetrical polygonal units along one side in some examples indicates that they were intended for half vaults and would have been doubled only along the symmetrical edge with a half star (cat. nos. 5, 11, 13a, 14, 84, 85, 88, 108–10). The irregular polygonal units could be manipulated by elongating or shortening while adjusting the muqarnas pattern to a given arch profile. Muqarnas patterns belonging to this group are sometimes contained in triangular or kite-shaped rhomboidal repeat units that could generate full vaults when multiplied or be used in geometric compartments and squinches at the transitional zones of vaults.

These drawings, largely intended for prefabricated plaster muqarnas vaults (sometimes inset with star-shaped tile plaques), can be grouped in terms of four basic types. The first consists of muqarnas quarter, half, or full vault patterns contained in square and rectangular frames that feature a star placed in the squinch corner (cat. nos. 5, 6, 11, 12, 14, 16, 17b, 18, 19b, 20–22, 24, 26, 79, 84, 85, 88, 92b, 98, 102, 106c, 107–10). In one example (cat. no. 88) irregular polygonal filler units have been arranged asymmetrically at the corner of a rectangular repeat unit that is not occupied by a star. Although most of these vault patterns have multiple tiers of star-studded muqarnas units, some of them constitute a distinctive subgroup characterized by fewer muqarnas tiers with less variegated stars. The latter are relatively simple muqarnas patterns for square bays, each of them featuring a twelve- or sixteen-pointed central stellate hood (cat. nos. 17b, 19b, 20–22, 26, 92b, 98, 107).

Permutations within this group primarily are caused by varying the number of radii that intersect the circumferences of differently spaced concentric circles and arcs along which multiple muqarnas tiers are formed. Smaller subsidiary systems of circles subdivided by equidistant radii surround each of the stars incorporated into the corbeled muqarnas tiers. The fan-shaped stellate hoods, the first rows of muqarnas units attached to

the hoods, and the circular orbits of stars obey a rigid geometry, but the spaces in between the stars and along the outer edges of the repeat units are often completed with polygonal or small prismatic filler units whose less precise geometry would allow them to be adapted to the varying profiles of arches during the construction process.

The radial grid systems that are responsible for generating these muqarnas projections are uninked dead drawings; the muqarnas units drawn in black ink are often, though not always, highlighted with stippling and color coding in red and black ink in order to differentiate spatial levels and to demarcate the boundaries of successively corbeled tiers. Stippling is generally used to indicate muqarnas units on a lower tier with respect to unstippled adjacent areas; for example the points of stars bending toward a higher plane are not stippled to differentiate them from stippled points occupying a lower spatial level. Sometimes, however, two different colors of stippling are used to distinguish the bent points of stars from unbent ones. Such stars with bent points are differentiated from flat stars on a single horizontal plane parallel to the horizon that are either unstippled, fully stippled, or colored (cat. nos. 17b, 18, 19b, 21a, 26a, 79, 82, 83a, 88, 92b, 107b, 108–10). Moreover, filler units in the shape of bipeds, triangles, or rhomboids are often color coded to make them stand out from other units; as such they accentuate the boundaries between different muqarnas tiers, which are either continuous rows or made up of star clusters. Some simple muqarnas projections in this group are, however, rendered in basic black-ink outlines with or without black stippling (cat. nos. 79, 98, 102, 106c, 107–110). These drawings provide less detailed graphic information about the spatial properties of their muqarnas projections, leaving more options for varied interpretations.

The second type consists of muqarnas quarter vault patterns contained in square or rectangular frames, with the squinch corner cut off by a diagonal line (cat. nos. 13a, 15a, 78b). The triangle created by the diagonal is filled in each case with a fragmentary muqarnas pattern, most likely meant to be used in the transition zone of the polygonal muqarnas vault depicted in the main pattern.

The third type (cat. nos. 4b, 17a, 80, 82, 83a, 111a) consists of kite-shaped rhomboidal or triangular repeat units that could be multiplied to create half or full vaults; they could also be used individually to fill the fragmented compartments of transitional zones in vaults.

The fourth type is a group of muqarnas fragments (cat. nos. 9, 10a, 10c, 13b, 15b, 17c, 78a, 81b) that either complement larger vault projections or are drawn in separate small frames. It is difficult to identify the purpose of all these fragments, most of which seem to be repeat units for linear muqarnas friezes or cornices that could be used along the inner or outer baselines of domes, in column capitals, and in corbeled minaret balconies (cat. nos. 9, 13b, 17c). Two of them depict semicircles with star-shaped muqarnas tiers that represent muqarnas cornices intended for the organ-pipe ribs of ribbed domes (cat. no. 81b). Muqarnas fragments that accompany larger vault patterns were probably meant to be used in the latter's transitional zone (cat. nos. 10a, 10c, 13b, 15b, 78a).

(IV.ii.b.) Muqarnas Vaults with Simple Quadrangular and Polygonal Compartments (cat. nos. 3, 19a, 23, 27, 87a, 89b, 95–97, 99–101, 103, 104, 106a–b, 112, 113)
Patterns belonging to this category are closely related to the relatively simple fan-shaped stellate muqarnas patterns of the previous group (cat. nos. 17b, 19b, 20–22, 26, 92b, 98, 107). Unlike the latter's fan-shaped hoods, their centers are occupied by large octagons (cat. nos. 3, 27, 95, 96, 104, 106b), rotated squares, and rotated squares forming eight- or twelve-pointed stars (cat. nos. 19a, 23, 97, 99–101, 103, 106a). In these patterns the surfaces of vaults are fragmented into groined compartments with relatively simple muqarnas units that are framed by squares, rectangles, rhombuses, and polygons, units that could be executed in plaster, brick, or wood. They either have no star-shaped muqarnas units or simply four- and eight-pointed stars limited to the square module with 45, 90, and 135 degrees. The majority of this group consists of repeat units or full patterns for square bays; a few examples represent rectangular and polygonal vaults. Their composition is sometimes guided by uninked composite radial and orthogonal grids (with proportionally related squares and

rectangles) that subdivide vaults into quadrangular compartments (nine-partite square bays being the most common) (cat. nos. 3, 19a, 23, 27, 87a, 89b, 95–97, 99–101, 103, 104, 112b). In some cases the large-scale muqarnas compartments are fragmented into smaller units, partially indicated at the edges (cat. nos. 95, 96, 100, 101, 103, 104). In other cases they consist of simple linear schemata in black ink that could either be used as shown or further subdivided into small muqarnas units (cat. nos. 97, 99). In one example (cat. no. 103) a drawing in black-ink outlines is provided with stippling and color coding at its lower left quarter to give more precise indications about its spatial properties that are otherwise ambiguous and open to different interpretations. A group of drawings belonging to this category, on the other hand, consists of repeat units for radial muqarnas vaults without any stars, composed of a stellate or polygonal central medallion surrounded by simple polygonal units with or without stippling (cat. nos. 106a–b, 112, 113). The remaining muqarnas vault patterns are fully marked with stippling and color coding (cat. nos. 3, 19a, 23, 27, 87a, 89b).

(IV.ii.c.) Shell-Shaped Radial Muqarnas Vaults (cat. nos. 2, 7, 25, 83b, 86, 87b)

Drawings belonging to this category depict radially symmetrical stellate muqarnas vault projections emanating from conchlike or shell-shaped fluted hoods that occupy most of the repeat unit. Their square and rectangular repeat units represent quarter or half vaults, the configuration of which varies according to the number of radii that divide the concentric arcs along which the muqarnas units are aligned. They have only a single tier of stars, unlike the majority of their multitiered fan-shaped counterparts. These drawings treat the squinch zone in different ways, just as the fan-shaped ones do. Some consist of quarter vaults in square frames, with the squinch corner occupied by a large star (cat. nos. 7, 86, 87b). Others are rectangular, square, or kite-shaped rhomboidal repeat units of polygonal muqarnas vaults accompanied by squinch zones filled with arch-nets of different configurations (cat. nos. 2, 25, 83b).

Shell-shaped radial muqarnas vault projections appear much less often in the Topkapı scroll than the fan-shaped type and its closely related variant with simple compartments. This is in keeping with the general Timurid-Turkmen preference for angular geometric forms that dominate curvilinear ones. The graphic conventions used in depicting shell-shaped muqarnas vault projections are the same as those used for the fan-shaped type; stippling and color coding highlight all of the black-ink drawings whose underlying radial grids remain uninked dead drawings. The stippled areas in the shell-shaped hoods indicate projections on a higher plane than the unstippled concave flutes. By contrast the stippled points of stars with bent points occupy a lower plane, as in the fan-shaped muqarnas patterns. Once again, filler units in the shape of bipeds, triangles, and rhomboids are differentiated from regular muqarnas units by color coding.

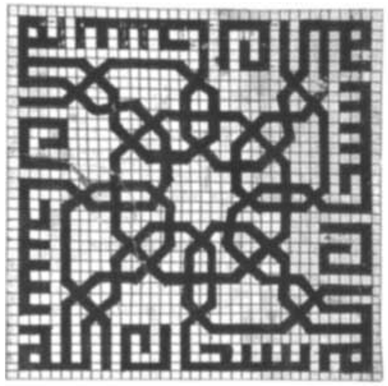
LIST OF DRAWINGS

The majority of the scroll patterns were generated from uninked, incised construction lines that appear on the paper as "dead drawings." These construction lines are sometimes redundant, featuring unnecessary or irregular elements unrelated to the final ink drawing. There are also cases where not all of the construction lines necessary for generating the final ink drawing are included in the "dead drawing," suggesting that some patterns may have been copied from earlier drawings acting as models. Coordinates occasionally were determined not by fully rendered construction lines but by indented compass points not always visible under the ink and coloring.

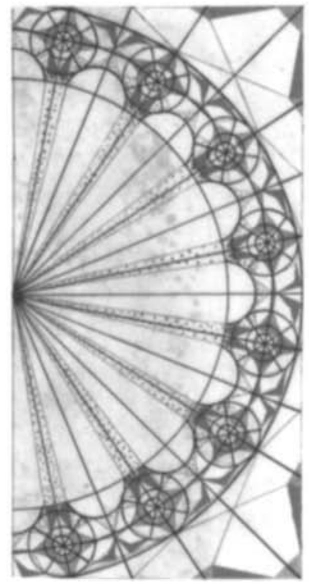
Given such variations and inconsistencies, some editing of the actual construction lines was required before attempting to reproduce them. An attempt has therefore been made to interpret the ideal underlying grid scheme used in generating each pattern. The illustrations that accompany the List of Drawings show the "edited" construction lines as dark black overlay drawings surprinted on photographs of the individual scroll segments.

The overlay drawings were rendered partially in a few complicated examples (see cat. nos. 38, 49) where it would have been redundant to reproduce the crisscross uninked construction lines of the whole pattern. Overlay drawings have not been provided for patterns generated by squared or triangulated grids that lack or have only a few uninked lines guiding their composition. In addition, most parts of the scroll have a continuous horizontal line passing through the center; this horizontal line is only incorporated in the overlay drawings when it was judged to be relevant to the pattern.

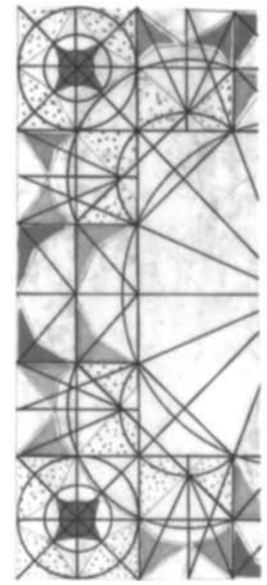
Some scroll patterns exhibit irregularities in rendering, such as missing lines, which would have been corrected during execution. Irregularities of this sort—also seen in the slightly varying dimensions of repeat unit frames and their grids—did not matter so long as the geometric schemes of patterns were legible to artisans already acquainted with the modular design language of *girih*s. The dimensions provided in the following list only indicate variations in measurement that exceed 0.1 cm. Dimensions are consistently given with height preceding width. The dimensions provided for cat. nos. 38 and 40–114, which have thick borders of approximately 0.4 cm, are measured from the interior of the frames.



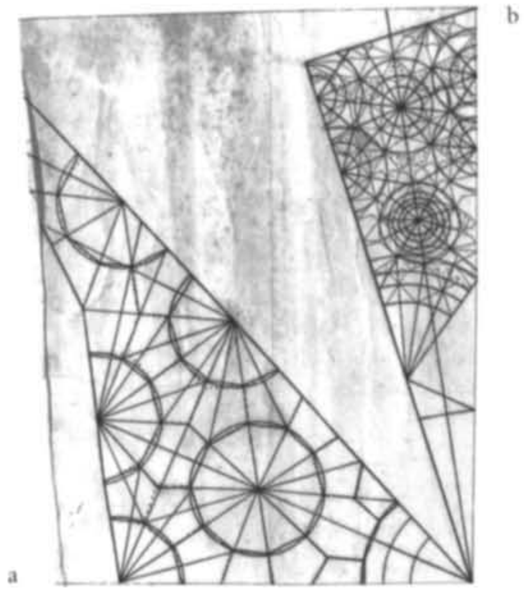
1.
Subject: Square kufic calligraphic panel based on a squared grid with a central eight-pointed star surrounded by an octagon and radiating polygonal patterns.
Dimensions: Contained in outer frame, 25.5 × 24 cm. The inked square is 16 × 16 cm. Each square of the grid measures 0.4 × 0.4 cm.
Condition: Fine.
Technique: The black-ink drawing is superimposed on a squared grid drawn in black ink. The grid was initially marked by ink lines indicating the squares to be filled in with ink. Some of these lines used in setting out the composition are still visible under the white paint that was used to cover up mistakes.
Inscriptions: "Subḥān Allāh" (Praise be to God), repeated four times.

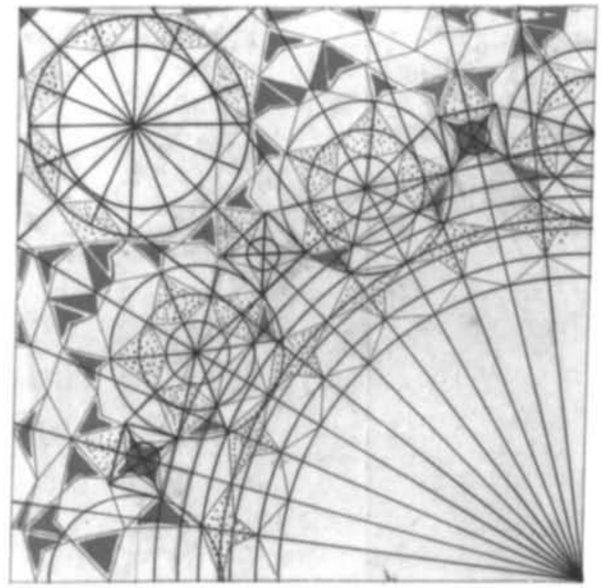


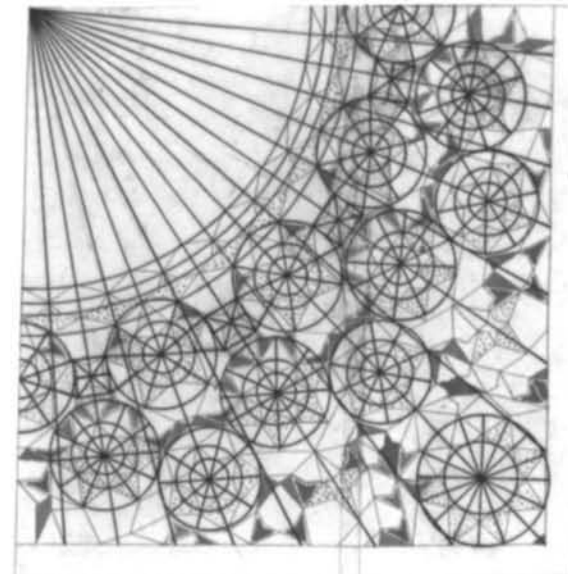
2.
Subject: Shell-shaped radial muqarnas half vault with a single row of four-pointed stars containing smaller four-pointed stars. Both squinch corners are filled by arch-nets; doubling the repeat unit would yield a sixteen-sided polygonal full vault.
Dimensions: 25.5 × 13 cm. The corner triangles have baselines measuring 10.7 cm and equal sides of 7.5 cm. The sides of the sixteen-sided vault measure 5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric semicircles with fifteen radii (full vault would have thirty-two-fold radial symmetry) and smaller subsidiary systems of concentric circles and arcs. The black-ink drawing is highlighted with stippling in black ink and color coding in black and red ink. The stippled areas in the shell-shaped muqarnas hood indicate projecting peaks on a higher plane that are differentiated from the concave flutes. One point of each four-pointed red star is left uncolored to show that it bends to a different plane; the arrow-shaped bipeds and other filler units are highlighted in color.



3.
Subject: Fragment of a stellate muqarnas vault for a square bay, based on a composite orthogonal and radial grid system, with a large central octagon inscribed in a square and small four-pointed corner stars contained in squares. The only other stars used in this composition, dominated by 45-, 90-, and 135-degree angles, are eight-pointed half stars. Most of the remaining large polygonal muqarnas compartments are framed by rectangles and squares.
Dimensions: 25.5 × 10.7 cm.
Condition: Pasted along the right edge. The missing half of this fragmentary pattern appears later in the scroll as cat. no. 27.
Technique: An uninked central circle with sixteen radii and smaller concentric circles and arcs in each corner, combined with an orthogonal grid of squares and rectangles. The black-ink drawing is highlighted with stippling in black ink; its arrow-shaped bipeds are color coded with black and red ink.



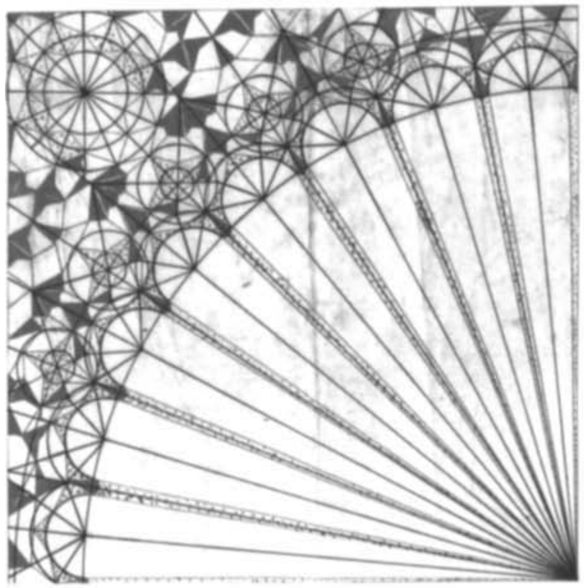


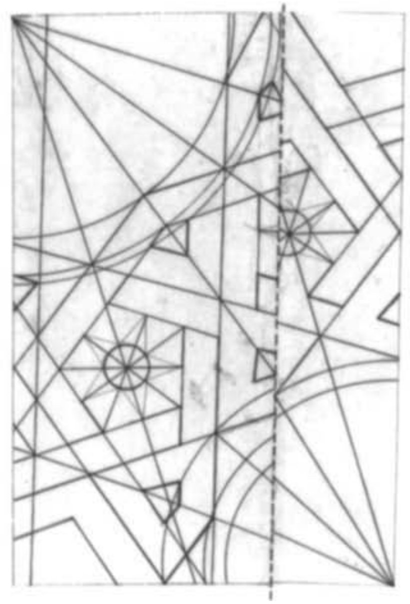


4.
Subject: (a) Vault fragment with black-dotted polygonal grid lines defining large decagons and small pentagons in contact; the star-and-polygon pattern that would have been generated by this grid has not been indicated.
Dimensions: Contained together with cat. no. 4b in a rectangular frame, 25.7 × 21 cm (top), 19.3 cm (bottom). The baseline of the vault fragment measures 16 cm.
Condition: Pasted along the left edge and in the middle. The design is partially cut off at the left.
Technique: Crisscross, irregular uninked radial grid lines define several circles and arcs containing decagons and decagon fragments; each is subdivided by equidistant radii that are prolonged to define the sides of pentagons. Not all of the uninked construction lines coincide with the black-ink drawing.
Subject: (b) Triangular one-twentieth repeat unit of a decagonal vault composed of stellate muqarnas elements consisting of four-, five-, and seven-pointed stars. When doubled, the repeat unit forms a rhomboidal kite-shape that could be used in the transitional zones of vaults.
Dimensions: The sides of the triangle measure 25.7 × 24.5 × 8 cm.
Condition: Pasted along the middle of the rectangular frame; intact.
Technique: Uninked radial grid lines of concentric circles and arcs subdivided by equidistant radii. The black-ink drawing superimposed on them has stippling in black ink to differentiate spatial levels (the unstippled points of stars bend toward different planes). The filler units have not been highlighted with color coding. The crisscross irregular uninked construction lines include many redundant lines.

5.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars alternating with four-pointed stars; the squinch corner is filled with a large eight-pointed star. The use of asymmetrical polygonal units along the upper edge indicates that the repeat unit was not meant for a full vault but for a half vault. (See "The Muqarnas" in the present volume for computer drawings and analysis.)
Dimensions: 25.7 × 25.7 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with eleven radii (half vault would have twenty-four-fold radial symmetry) and smaller subsidiary systems of concentric circles alternating with uninked squares, each containing a small circle and crossed diagonals. The black-ink drawing has stippling in black ink to differentiate spatial levels, and its filler units in the shape of bipeds and triangles are color coded in red and black ink to demarcate the boundaries of muqarnas tiers surrounding the stars.

6.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by two alternating rows of four- and five-, and five- and six-pointed stars. The squinch corner, filled with a large eight-pointed star, is flanked by a pair of four-pointed stars forming a subsidiary row.
Dimensions: Contained in a square repeat unit, 25.7 × 25.7 cm. Inner square measures 24 × 24 cm.
Condition: Pasted toward the middle where the design has slipped slightly. Some of the bipeds along the right side of the star in the squinch corner are left uncolored unlike their symmetrical counterparts.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (full vault would have sixty-four-fold radial symmetry) and smaller subsidiary systems of concentric circles that in the first row alternate with uninked small squares. The black-ink drawing has stippling in black and color coding in black and red ink to differentiate spatial levels. The unstippled points of stars bend toward different planes, and the filler units are color coded to delineate the relatively continuous boundaries of corbeled muqarnas tiers.

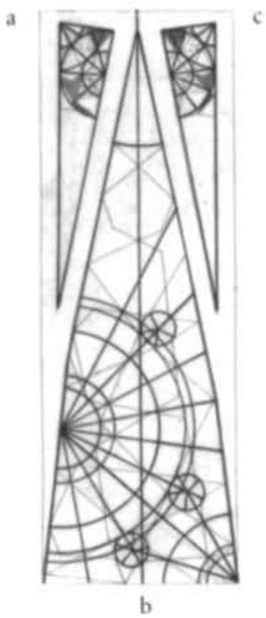




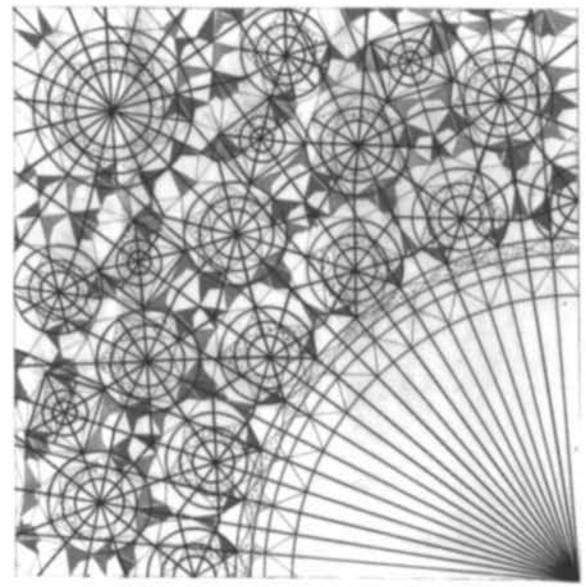
7.
Subject: Shell-shaped radial muqarnas quarter vault with a single row of four-pointed stars; the squinch corner is filled with a large eight-pointed star.
Dimensions: 25.7 × 25.7 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (full vault would have sixty-four-fold radial symmetry) and smaller subsidiary systems of concentric circles and arcs. Stippling and color coding used to differentiate spatial levels and to highlight bipeds and other filler units as in cat. no. 2.

8.
Subject: Quarter repeat unit for strapwork pattern with stars and polygons generated by ten-pointed quarter stars at the upper left and lower right corners.
Dimensions: 25.7 × 17.7 (top), 17.2 cm (bottom).
Condition: Pasted at the right half where the originally symmetrical design has slipped.
Technique: The uninked radial grid lines of the two ten-pointed quarter stars occupying diagonal corners (contained in concentric quarter circles with four radii each) generate the pattern drawn in black ink. These are complemented by uninked parallel lines, not all of them related to the final design. They define pentagons, subdivided by ten radii, in contact with rhomboids. An uninked diagonal axis of symmetry connecting the starred corners intersects at the middle of the composition with an unindicated oblique axis of symmetry along which the five-pointed stars are aligned. An uninked vertical axis of symmetry bisects the rectangular repeat unit into two equal halves. The pattern is also symmetrical along a second uninked oblique axis passing through its center. The elements of design are aligned along uninked lines forming an N shape (the diagonal connecting the starred corners and the first radii emanating from those corners that bisect the five-pointed stars).

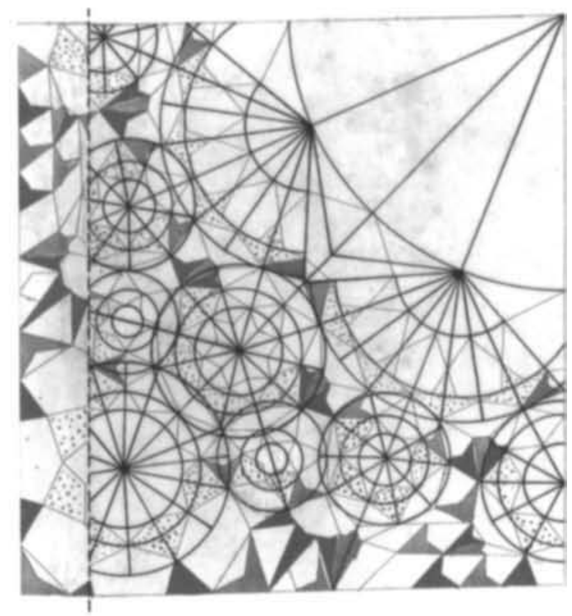
9.
Subject: (a) Rectangular repeat unit for a stellate muqarnas fragment, most likely a linear frieze or cornice.
Dimensions: Contained together with cat. no. 9b–d in a rectangular frame, 25.7 × 4 cm. The repeat unit measures 3 × 4 cm.
Condition: Fine. Hole at the right.
Technique: Uninked radial grid lines of concentric quarter circles subdivided by two radii emanating from the upper left corner. The black-ink drawing is stippled in black ink to differentiate spatial levels.
Subject: (b) Same as cat. no. 9a. The lower right corner has a twelve-pointed quarter star.
Dimensions: 3.5 × 4 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles subdivided by five equidistant radii emanating from the lower right corner. The pattern drawn in black ink is highlighted with black stippling and color coding in red and black ink.
Subject: (c) Same as cat. no. 9a. The bottom edge has a six-pointed half star.
Dimensions: 2.5 × 4 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric semicircles subdivided by five equidistant radii emanating from the center of the repeat unit's bottom edge. Coding same as cat. no. 9b.
Subject: (d) Same as cat. no. 9a. The upper and lower right corners have twelve-pointed quarter stars, and the middle of the repeat unit is occupied by a five-pointed star.
Dimensions: 9.5 × 4 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles subdivided by five radii at the upper and lower right corners with smaller concentric circles of ten radii inserted in between. An uninked horizontal axis of symmetry bisects the repeat unit into two identical halves. Coding same as cat. no. 9b. The unstippled points of the five-pointed star bend to a different level.



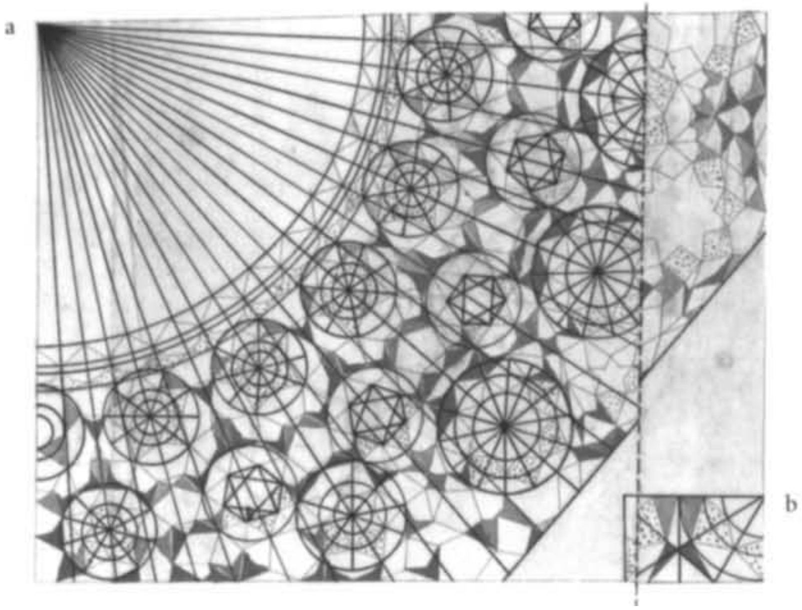
10.
Subject: (a, c) Triangular repeat units of muqarnas details, probably for vault sections or transitional zones of vaults.
Dimensions: Contained in a rectangular frame, 25.7 × 8.7 cm. Each triangle measures 2.5 × 13 × 13 cm.
Condition: Fine.
Technique: Uninked concentric radial grids of quarter and half circles subdivided by equidistant radii generate the muqarnas units. The black-ink drawings feature black stippling and red and black color coding. The unstippled points of stars bend toward different levels, and the filler units are accentuated.
Subject: (b) Curved triangular vault section providing the one-twelfth repeat unit of a polygonal vault decorated with five- and ten-pointed stars interlocking with hexagons and rhomboids.
Dimensions: The triangle has a baseline of 8.7 cm and is 24.7 cm high.
Condition: Fine. There is a redundant line near the half star along the left edge.
Technique: Drawn in black ink over an uninked radial grid with concentric arcs and small circles subdivided by equidistant radii. An uninked vertical line bisects the triangular repeat unit, which is crisscrossed with redundant uninked lines that do not always coincide with the final pattern.



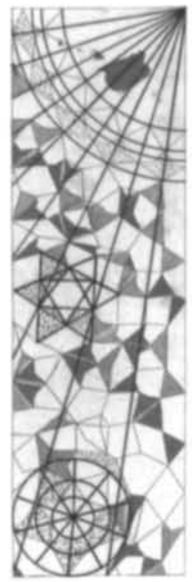
11.
Subject: Fan-shaped radial muqarnas quarter vault starting with hexagons and arrow-shaped double bipeds, followed by two rows of five- and six-pointed stars and a third row of alternating four- and five-pointed stars. The squinch corner is occupied by a large nine-pointed star. The use of asymmetrical polygonal units along the upper right edge indicates that the repeat unit was not meant for a full vault but for a half vault.
Dimensions: 25.7 × 25.7 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with nineteen radii (half vault would have forty-fold radial symmetry) and smaller subsidiary systems of concentric circles alternating with uninked squares containing concentric circles subdivided by radii. The black-ink drawing has stippling in black and color coding in red and black ink to differentiate spatial levels. The unstippled points of stars bend toward different planes, and biped-shaped or triangular filler units are highlighted in color to demarcate the boundaries of muqarnas tiers.



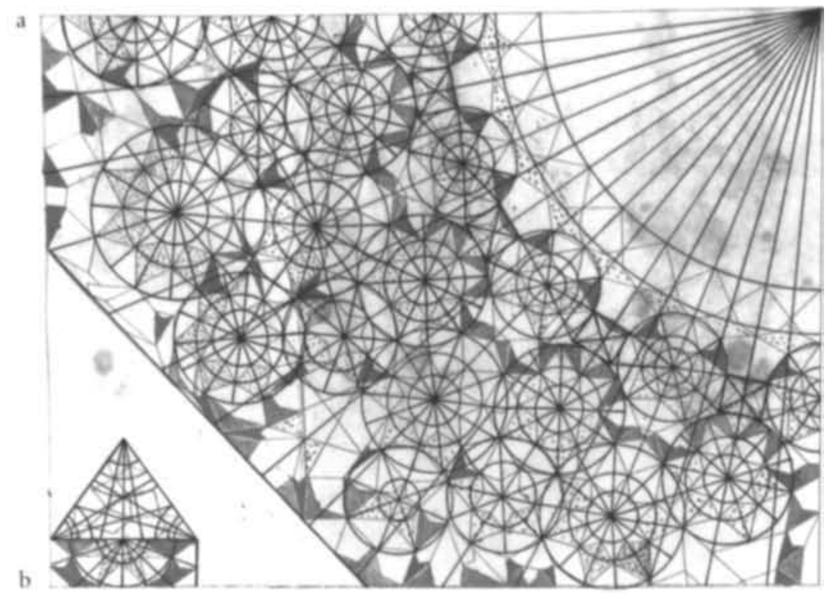
12.
Subject: Fan-shaped radial muqarnas quarter vault generated from a sixteen-pointed quarter star at the upper right corner. A row of one-third twelve-pointed stars alternating with pentagons is followed by hexagons, arrow-shaped double bipeds, and a continuous row of two types of five-pointed stars, with a six-pointed star at the center of the composition. The squinch corner is filled with a large eight-pointed star.
Dimensions: 25.7 × 24.7 cm.
Condition: Pasted near the left edge where part of the design is missing.
Technique: An uninked quarter circle at the upper right corner is subdivided by three radii (full vault would have sixteen-fold radial symmetry). Along the first and third radii are uninked one-third circles subdivided by seven radii and followed by smaller subsidiary systems of concentric circles; see cat. no. 17a for a similar composition. Stippling and color coding same as cat. no. 11.



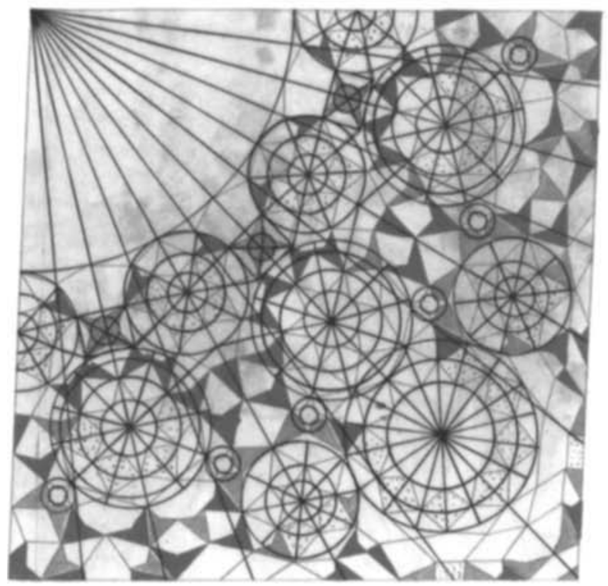
13.
Subject: (a) Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by two rows of five- and six-pointed stars and a third row of alternating five- and seven-pointed stars. A slight asymmetry is caused by the rectangular format. The use of asymmetrical polygonal units along the lower left edge indicates that the repeat unit was not meant for a full vault but for a half vault. Since its squinch corner is cut off, the design was probably intended for a vaulted space in the shape of a half octagon.
Dimensions: Contained in a rectangular repeat unit, 25.7 × 33.5 cm.
Condition: Pasted near the right edge where the design has slipped.
Technique: Uninked radial grid lines of concentric quarter circles with twenty-one radii (half vault would have forty-four-fold radial symmetry) and smaller subsidiary systems of concentric circles subdivided by equidistant radii; some of them have hexagons inscribed with six-pointed stars. Stippling and color coding same as cat. no. 12.
Subject: (b) The empty corner triangle is filled with the rectangular repeat unit of a muqarnas fragment probably intended for a cornice or frieze running along the baseline of the polygonal vault depicted in cat. no. 13a.
Dimensions: 4 × 6.5 cm.
Condition: The originally symmetrical design, of which the left part is partially missing, was deformed by the pasting of paper.
Technique: The original pattern was generated by uninked concentric quarter circles at the upper right and left corners, each subdivided by two radii. Coding the same as cat. no. 13a.

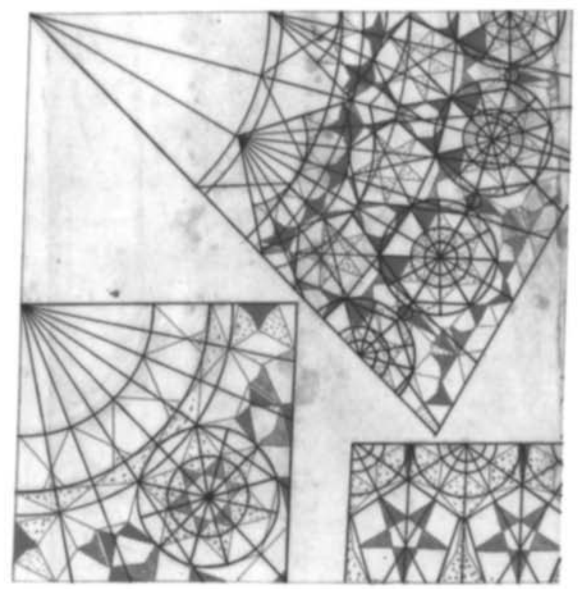


14.
Subject: Fan-shaped radial muqarnas quarter vault adapted to the elongated rectangular format of the repeat unit. Rows of hexagons and arrow-shaped double bipeds, followed by filler elements, polygons, a six-pointed star, and a five-pointed corner star. The repeat unit was probably meant to be doubled and used for a long and narrow space; the irregular polygonal units along the right edge suggest that it was not meant to be quadrupled.
Dimensions: 25.7 × 7.7 cm.
Condition: Holes at the top.
Technique: Uninked radial grid lines of concentric quarter circles with nine radii (half vault would have twenty-fold radial symmetry), two superimposed six-pointed stars, and smaller concentric circles. Stippling and color coding same as cat. no. 13. The uninked construction lines reflect the loose geometry of this muqarnas pattern, dominated by asymmetrically arranged filler units consisting of bipeds, triangles, and polygons.



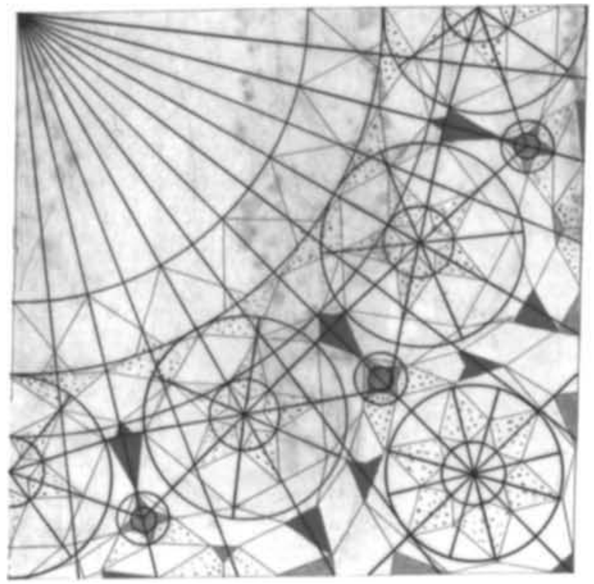
15.
Subject: (a) Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by multiple rows of four-, five-, six-, seven-, and eight-pointed stars. The design is asymmetrical because of the rectangular format of the repeat unit. The empty triangular squinch corner of the octagonal vault is provided with a complementary pattern.
Dimensions: Contained in a rectangular frame, 25.7 × 35 (top), 34.5 cm (bottom). The triangular squinch corner measures 21 × 14.3 × 14.3 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (full vault would have sixty-four-fold radial symmetry) and smaller subsidiary systems of concentric circles, the first row of which alternates with rectangles. Stippling and color coding used to differentiate spatial levels and to demarcate the boundaries of tiers composed of relatively continuous rows of stars that are not separated into clusters by filler units.
Subject: (b) Rectangular and triangular repeat units for muqarnas fragments probably intended to be used in the transitional zone of the octagonal dome depicted in cat. no. 15a.
Dimensions: The rectangle measures 2 × 6.5 cm. The triangle has a base of 6.5 cm and two equal sides of 5.5 cm.
Condition: Fine.
Technique: The rectangular muqarnas pattern is generated by uninked concentric semicircles subdivided by seven radii emanating from the midpoint of the upper edge of the repeat unit. The other pattern is generated by uninked concentric arcs at each corner of the triangle; the lower arcs are each divided by two radii, those at the apex of the triangle by three radii. Stippling and color coding are used only in the rectangle.



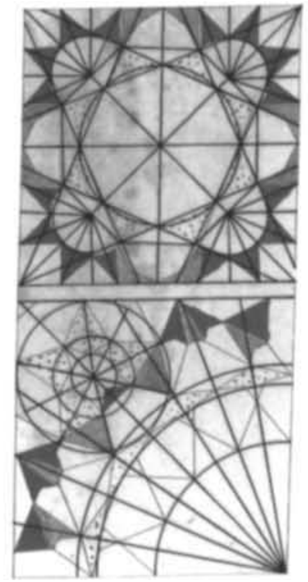


16.
Subject: Fan-shaped radial muqarnas quarter vault starting with alternating pentagons and trisected hexagons (each with three kite-shaped rhomboids), followed by two rows of four- and five-, and four- and six-pointed muqarnas stars. The squinch corner, filled with a large nine-pointed star, is flanked by two five-pointed stars forming a subsidiary row.
Dimensions: 25.7 × 25.7 cm.
Condition: Pasted near the left edge; intact. A line is missing from the first row where the hexagon should have been subdivided into a pentagon.
Technique: Uninked radial grid lines of concentric quarter circles with eleven radii (full vault would have forty-eight-fold radial symmetry) and smaller subsidiary systems of concentric circles the first row of which alternates with rectangles, each inscribed with a small circle subdivided by radii. Stippling and color coding same as cat. no. 15, but here color-coded filler units define star clusters that do not constitute continuous rows as in cat. no. 15.

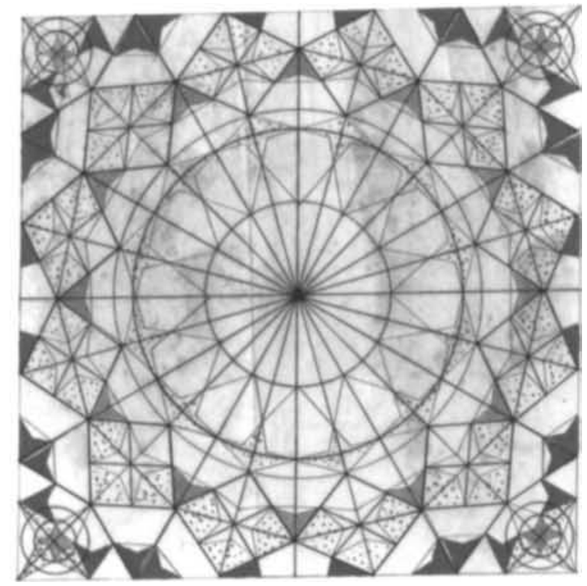
17.
Subject: (a) Rhomboidal one-eighth repeat unit of an octagonal fan-shaped radial muqarnas vault, starting with rows of sixteen-pointed quarter stars alternating with rhomboids as in cat. no. 12. These are followed by arrow-shaped double bipeds, hexagons, and two rows of unbent five- and six-pointed stars contained in polygons. The two complementary drawings that accompany it, cat. no. 17 b–c, were probably intended to be used in conjunction with this octagonal muqarnas vault. They all include unbent stars on a single plane contained in polygons.
Dimensions: Contained in a frame, 25.7 × 24.5 (top), 25 cm (bottom). The rhomboid-shaped repeat unit deformed by the irregular pasting measures 24.5 × 26.5 × 12 × 8.5 cm.
Condition: Pasted along the right edge where some of the design has disappeared. Hole at the top.
Technique: Uninked radial grid lines of concentric arcs with two radii (full vault would have twenty-four-fold radial symmetry) and smaller subsidiary systems of circles. The rhomboidal repeat unit is divided into three sections by two uninked radii emanating from the upper left corner. Along the horizontal upper edge of the repeat unit and the second radius are drawn concentric arcs subdivided by three and seven radii, respectively (see cat. no. 12 for a similar composition). These are followed by uninked pentagons and hexagons in circles alternating with small circles. Stippling and color coding are used to differentiate spatial levels and the boundaries of tiers. The stippling of the stars indicates that they do not have bent points.
Subject: (b) Fan-shaped radial muqarnas quarter vault starting with a row of hexagons and arrow-shaped double bipeds. It has no intermediary rows of stars; a six-pointed unbent star occupies the squinch corner, framed by an irregular hexagon.
Dimensions: 12.5 × 12.5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry) and concentric circles at the lower right corner. Stippling and color coding same as cat. no. 17a.
Subject: (c) Rectangular repeat unit of stellate muqarnas fragment, probably for a linear cornice used along the base of the octagonal vault depicted in cat. no. 17a. It features unbent five-pointed stars contained in pentagons and six-pointed half stars along its upper edge.
Dimensions: 6.2 × 9.3 (top), 9.7 cm (bottom).
Condition: Right edge slightly cut off.
Technique: Along the midpoint of the upper edge of the repeat unit a series of concentric uninked semicircles with five radii are flanked by concentric quarter circles with two radii at the two upper corners. Three uninked vertical lines subdivide the repeat unit into four equal strips. Stippling and color coding same as cat. no. 17b.



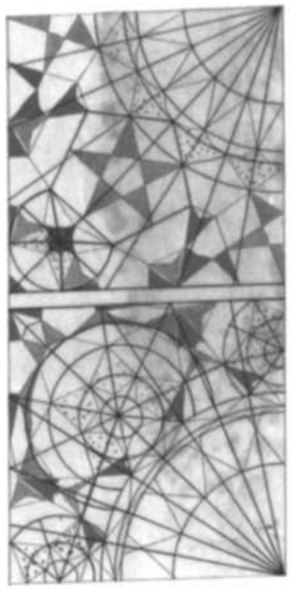
18.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a row of five-pointed stars contained in pentagons, and a subsidiary row of four-pointed small stars. The squinch corner is occupied by a large six-pointed star.
Dimensions: 25.7 × 25.5 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles with eleven radii (full vault would have forty-eight-fold radial symmetry) and smaller subsidiary systems of concentric circles. Stippling and color coding are used to differentiate spatial levels and the boundaries of polygonal star clusters surrounded by colored bipeds, triangles, and other filler units. The black-stippled stars do not have bent points.



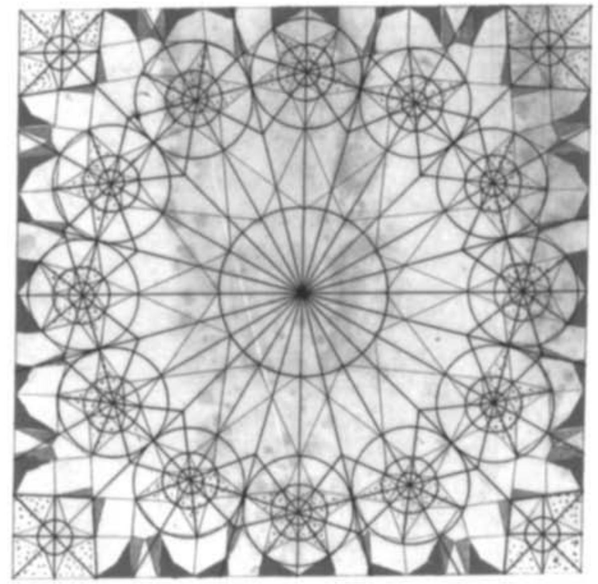
19.
Subject: (a) Stellate muqarnas full vault for a square bay based on a composite radial and orthogonal grid. At the center two rotated squares form a star octagon, each corner has an eight-pointed half star. The pattern is based on 45-, 90-, and 135-degree angles.
Dimensions: Contained in a rectangular frame, 25.7 × 12.5 cm. Square repeat unit measures 12.5 × 12.5 cm.
Condition: Fine.
Technique: An uninked composite radial grid with a central circle subdivided by eight radii that coincide with the diagonal, horizontal, and vertical axes of symmetry governing the composition. Two rotated squares with extended sides that intersect the outer square frame of the repeat unit are inscribed in an uninked central octagon. An uninked semicircle with seven radii (whose diameter coincides with the alternating sides of the uninked octagon) is placed in each of the four corners. Stippling and color coding are used to differentiate spatial levels.
Subject: (b) Fan-shaped radial muqarnas quarter vault starting with hexagons and arrow-shaped double bipeds. It has no intermediary rows of stars; the squinch corner has a five-pointed unbent star contained in a larger stippled five-pointed star whose fifth point is eliminated.
Dimensions: 12.5 × 12.5 cm.
Condition: Fine.
Technique: Uninked composite radial grid lines of concentric quarter circles with seven radii emanating from the lower right corner (full vault would have thirty-two-fold radial symmetry) and subsidiary concentric circles at the upper left corner. Stippling and color coding are used to differentiate spatial levels and to highlight filler units in the shape of bipeds and triangles.



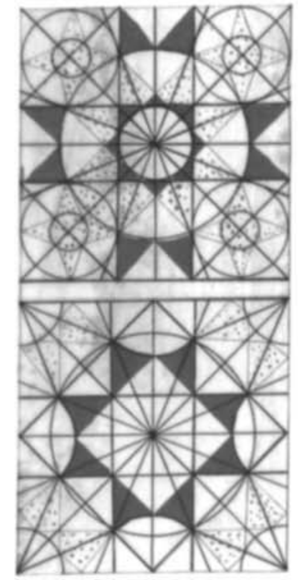
20.
Subject: Fan-shaped muqarnas full vault for a square bay based on a radial grid, with a central twelve-pointed star surrounded by rows of hexagons, arrow-shaped double bipeds, and a single row of four-pointed stars contained in rhombuses. Each corner contains a four-pointed star.
Dimensions: 25.5 × 25.5 cm.
Condition: Pasted near the middle; intact. Hole at the upper left corner.
Technique: Uninked radial grid with concentric circles at the center subdivided by twenty-four radii. Along alternating radii are placed rhombuses whose uninked diagonals and bisectors generate four-pointed stars. At each corner of the repeat unit are uninked small circles. Stippling and color coding same as cat. no. 19b.



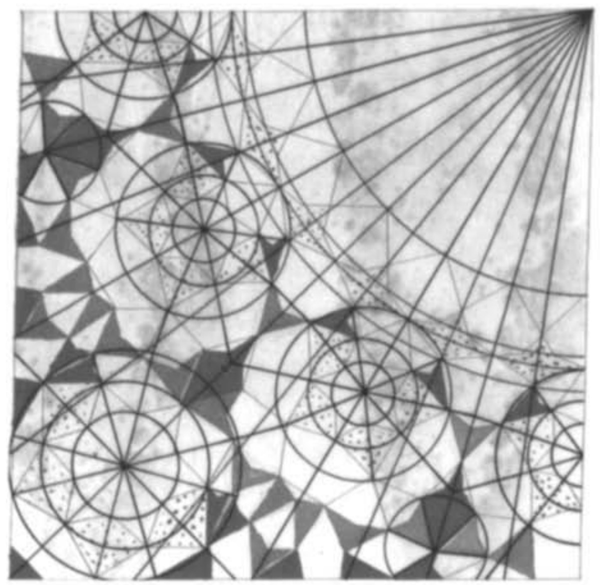
21.
Subject: (a, b) Fan-shaped muqarnas quarter vaults with no intermediary row of stars. A five-pointed star occupies the squinch corner of cat. no. 21b, whereas in cat. no. 21a a five-pointed star framed by a pentagon is attached to a four-pointed star contained in a hexagon in the squinch corner.
Dimensions: Contained in a rectangular frame, 25.7 × 12.5 cm. Each square repeat unit measures 12.5 × 12.5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry) complemented by uninked smaller arcs. Stippling and color coding used to differentiate spatial levels and to accentuate the biped- and triangle-shaped filler units surrounding the stars at each corner. The red five-pointed star contained in a pentagon in cat. no. 21a is unbent, unlike the one in cat. no. 21b whose unstippled point bends toward another plane.



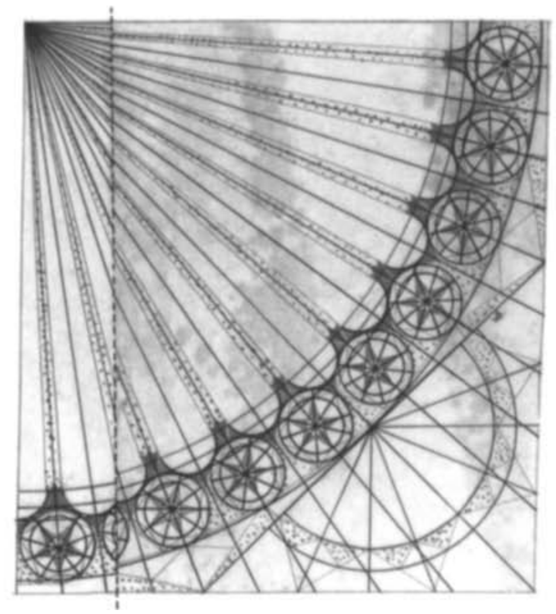
22.
Subject: Fan-shaped muqarnas full vault for square bay based on a radial grid, with a central twelve-pointed star, surrounded by a single row of five-pointed stars; each squinch corner has a four-pointed star.
Dimensions: 25.7 × 25.7 cm.
Condition: Pasted regularly near the right edge. Holes at the upper left corner.
Technique: An uninked central circle with twenty-four radii surrounded by twelve smaller subsidiary systems of concentric circles, each subdivided by ten radii. At each corner are rhombuses containing an uninked small circle subdivided by eight radii. Stippling is used to indicate the bent points of stars, and color coding is used to highlight filler units distributed along the outer frame of the repeat unit.



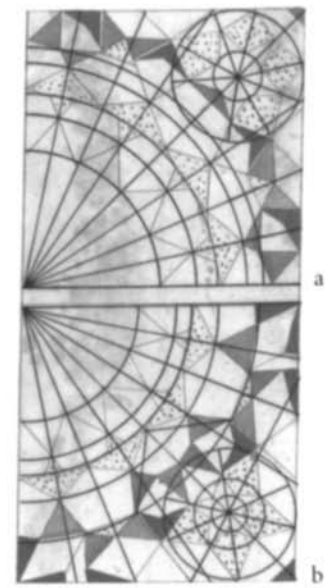
23.
Subject: (a) Stellate muqarnas full vault for a square bay based on a composite orthogonal and radial grid, with a central star octagon created by two rotated squares that grow into a larger octagon. Small four-pointed stars contained in squares occupy each corner.
Dimensions: Contained in a rectangular frame, 25.7 × 12.3 cm. The square repeat unit measures 12.3 × 12.3 cm.
Condition: Fine. The rhomboidal compartment inside the square at the lower left corner is stippled by mistake.
Technique: Uninked concentric circles at the center subdivided by sixteen radii are supplemented by uninked squares containing concentric circles at each corner. The full vault has sixteen-fold radial symmetry, and the uninked orthogonal grid lines divide it into nine compartments of squares and rectangles. The black drawing is coded with stippling and coloring in black to differentiate spatial levels.
Subject: (b) Stellate muqarnas full vault for a square bay based on a composite radial and orthogonal grid, with a central square contained in a rotated square and eight-pointed quarter stars at the corners. This is a nearly exact replica of cat. no. 99 (with the exception of the central square), which only provides the schematic black-ink outlines of the same pattern and omits most of the uninked construction lines.
Dimensions: 12.3 × 12.3 cm.
Condition: Fine.
Technique: An uninked central circle with sixteen radii and an uninked rotated square whose corners mark the centers of the outer square frame. Four uninked arcs are drawn from these four points and from the four corners of the repeat unit; the latter are subdivided by three radii. Pairs of uninked horizontal and vertical axes subdivide the repeat unit into a nine-partite orthogonal grid of squares and rectangles. The black line drawing is stippled and color coded in black ink as in cat. no. 23a.



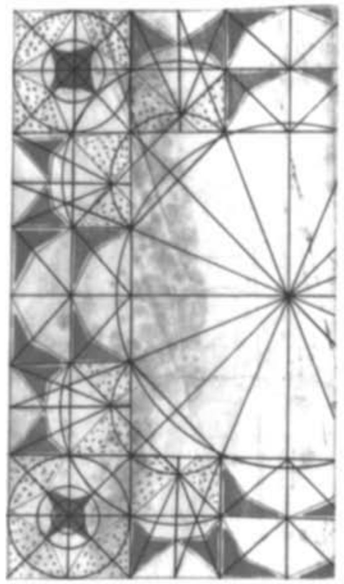
24.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars; the squinch corner is occupied by a six-pointed star.
Dimensions: 25.7 × 25.7 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with eleven radii (full vault would have forty-eight-fold radial symmetry) and smaller subsidiary systems of concentric circles. Black-ink drawing with stippling in black and color coding in red and black to differentiate spatial levels and to highlight filler units surrounding the star clusters in different tiers.



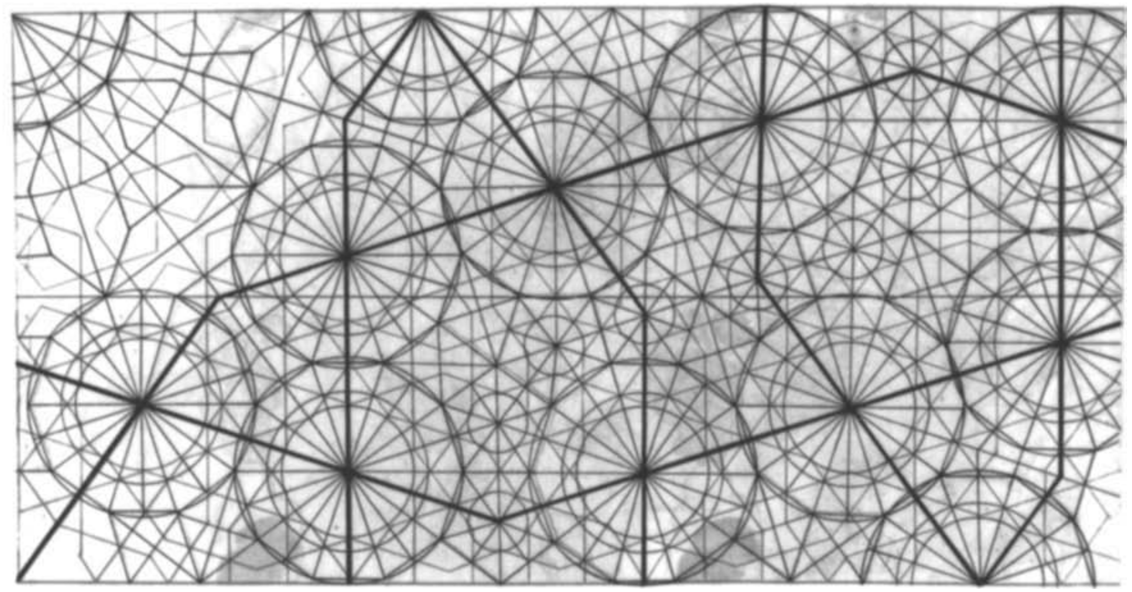
25.
Subject: Shell-shaped radial muqarnas quarter vault surrounded by a single row of five-pointed stars, followed by arch-nets that fill the corners of the octagonal dome. The triangular squinch corner is provided with a complementary drawing of a semicircular stellate arch-net that probably would have been used in the dome's transitional zone.
Dimensions: 25.5 × 23.3 (top), 23 cm (bottom). The base of the equilateral squinch triangle measures 21 cm; its two sides are 14.7 cm each.
Condition: Pasted near the left edge where the partly missing design has slipped. Hole near the middle of the right edge.
Technique: Uninked radial grid lines of concentric quarter circles with nineteen radii (full vault would have eighty-fold radial symmetry) and smaller systems of subsidiary concentric circles and arcs. Stippling and color coding same as cat. nos. 2 and 7. The triangular squinch corner contains two uninked concentric semicircles with seven radii.



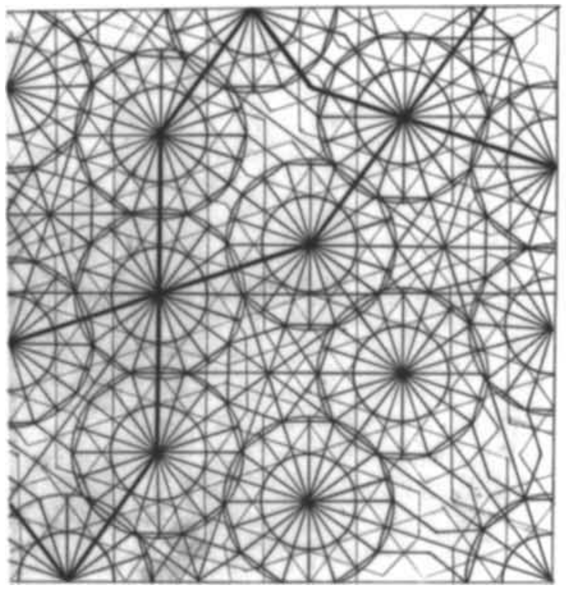
26.
Subject: (a, b) Fan-shaped quarter muqarnas vaults for square bays starting with rows of hexagons, arrow-shaped double bipeds, and pentagons without intermediary rows of stars. Their squinch corners have a five-pointed star.
Dimensions: Contained in a rectangular frame, 25.5 × 12.3 cm. Each square repeat unit measures 12.3 × 12.3 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry) and smaller concentric circles in the squinch corners. Stippling and color coding are used to differentiate spatial levels and to highlight filler units demarcating tiers. Although the unbent five-pointed corner star with one point missing in cat. no. 26a is on a single plane, that of cat. no. 26b has one bending point that is unstippled.



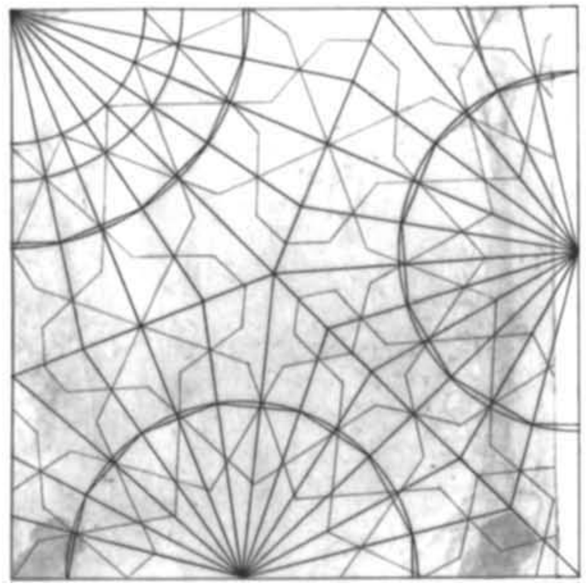
27.
Subject: Fragment of a stellate muqarnas vault based on a composite orthogonal and radial grid, with a large central octagon inscribed in a square and four-pointed small corner stars contained in squares. This is the missing half of cat. no. 3.
Dimensions: 25.5 × 14.7 cm.
Condition: Pasted along the right edge. The missing side of this fragmentary design appears earlier in the scroll as cat. no. 3. Hole at the upper left corner.
Technique: Same as cat. no. 3.



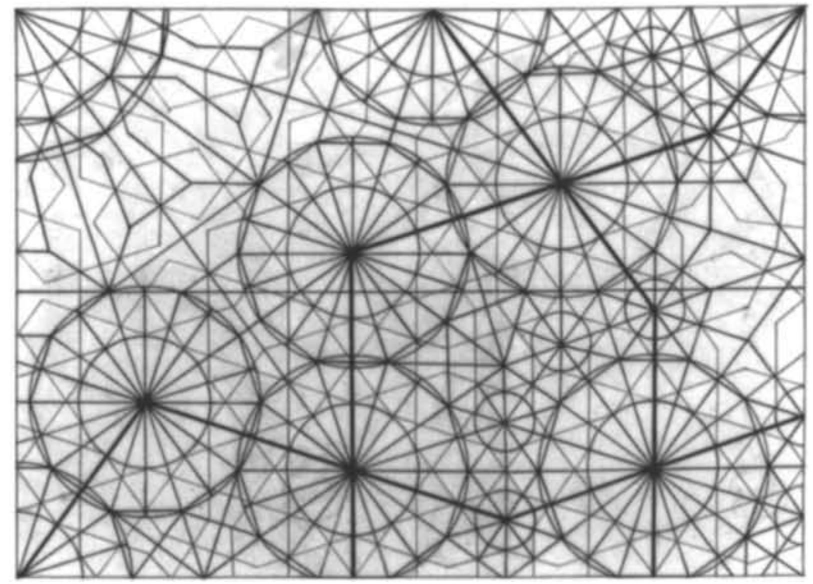
28.
Subject: Quarter repeat unit of a two-dimensional star-and-polygon design with three superimposed layers of pattern. The solid orange lines form a large-scale grid of stars and polygons in contact (ten-pointed quarter stars, rhomboids, irregular hexagons, and double trapezoids in the shape of bow ties). They emanate from a ten-pointed quarter star at the upper left corner and another quarter star of the same shape at the missing lower right corner, partially torn off. The points where the orange grid lines, passing through several circle centers, intersect determine the centers of all the ten-pointed stars drawn in black ink and of some of the five-pointed stars. The red-dotted polygonal grid consists of decagons in contact with pentagons and rhombuses (with double trapezoids in the shape of bow ties and elongated hexagons at the upper left and lower right corners, within the areas defined by the orange quarter stars). The sides of each red-dotted polygon are bisected by two crossing lines in black ink that meet each other to form a smaller-scale pattern of five- and ten-pointed stars interlocking with polygons.
Dimensions: 25.5 × 49.5 cm.
Condition: Pasted along the right and left edges. Right side missing.
Technique: Uninked radial grid lines of concentric circles with ten and twenty radii, respectively, surround each of the stars drawn in black ink and the red-dotted polygons in contact. Orange lines over black dots, red-dotted lines, and black lines superimposed on the uninked radial grid lines represent three different layers of pattern. The orange lines are formed by joining some radii of the circles containing the ten-pointed stars. Although the orange and black lines (defining proportionally related star-and-polygon patterns based on five- and ten-pointed shapes in differing scales) could be juxtaposed in the final pattern, the red-dotted polygonal construction lines would have been eliminated.



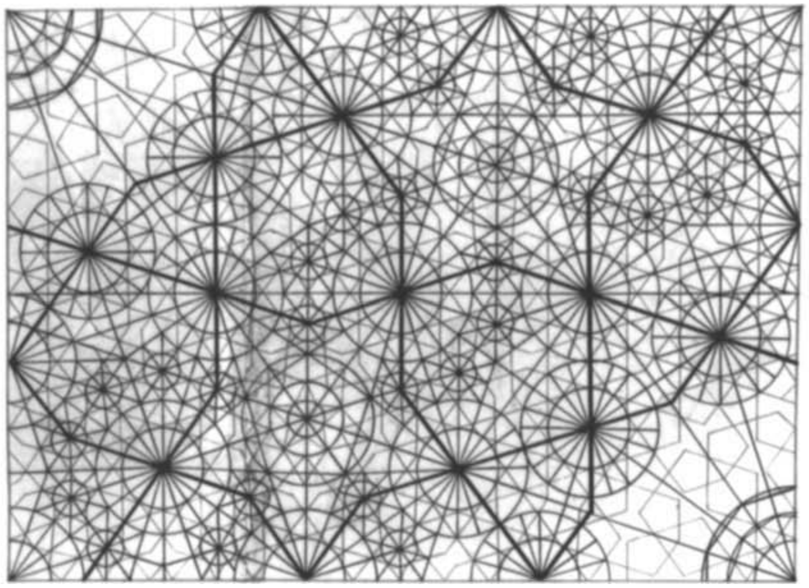
29.
Subject: Quarter repeat unit of a star-and-polygon pattern with two superimposed layers. The large-scale grid with black dots gone over in solid orange defines stars and polygons in contact (a ten-pointed quarter star and arrow-shaped six-pointed polygons). It emanates from a ten-pointed quarter star at the lower right corner and another quarter star of the same shape at the missing upper left corner, partially torn off. The points where the orange grid lines, which join several circle centers by linking their radii, intersect determine some of the ten-pointed star centers of the pattern drawn in black ink. The latter consists of ten-pointed stars interlocking with pentagons and other polygons.
Dimensions: 25.5 × 24.5 (top), 24.3 cm (bottom).
Condition: Pasted along the left edge where part of the design is missing.
Technique: Uninked radial grid lines of concentric circles with twenty radii surround each of the ten-pointed stars drawn in black ink. The black-dotted lines gone over in solid orange and the black lines represent two different layers of pattern, proportionally related to one another. Each could be used alone or together. The pattern in black ink is generated by uninked decagons in contact with elongated hexagons, star pentagons, and double trapezoids in the shape of bow ties.



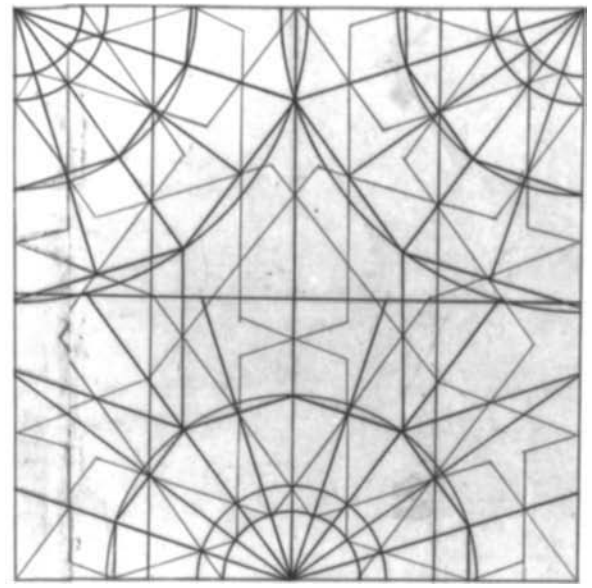
30.
Subject: Quarter repeat unit of a star-and-polygon pattern without dotted or solid grid lines, composed of a sixteen-pointed quarter star at the upper left corner and two thirteen-pointed half stars along the bottom and right edges. These large-scale stars are surrounded by subsidiary five-pointed stars, star fragments, and arrow-shaped double bipeds interlocking with other polygons. The center of the composition is occupied by a triple-armed irregular polygon terminating with star fragments.
Dimensions: 25.7 × 24.7 cm.
Condition: Pasted along the right edge where part of the design is missing.
Technique: Uninked radial grid lines of concentric quarter and half circles with seven and twelve radii, respectively, generate the quarter and half stars. These radii meet along three uninked axes of symmetry that cut the square repeat unit into three congruent parts. The three axes intersect with three others at the center of the repeat unit. The points at which the latter three uninked axis lines meet the outer frame of the repeat unit determine the centers of the quarter and half stars drawn in black ink.



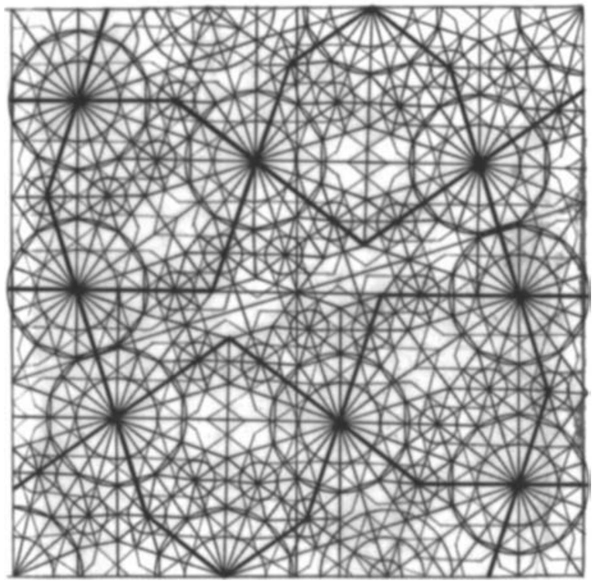
31.
Subject: Quarter repeat unit of a pattern with two superimposed layers, both of them based on five- and ten-pointed stars and polygons. The black-dotted grid gone over in solid orange, defining stars and polygons in contact, grows from a ten-pointed quarter star at the upper left corner and a five-pointed half star along the right edge that interlock with irregular hexagons. The points at which the orange grid lines, created by joining some radii of uninked circles, meet determine the centers of the ten-pointed stars drawn in black ink. The orange grid is proportionally related to the smaller-scale pattern drawn in black ink, composed of ten- and five-pointed stars interlocking with pentagons and other polygons.
Dimensions: 25.7 × 35.5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric circles and arcs with twenty and ten radii, respectively, surround each of the stars drawn in black ink. They form an uninked grid of polygons in contact, consisting of decagons, pentagons, and rhombuses. The upper left corner, delineated by the orange quarter star, features uninked elongated hexagons alternating with double trapezoids in the shape of bow ties.



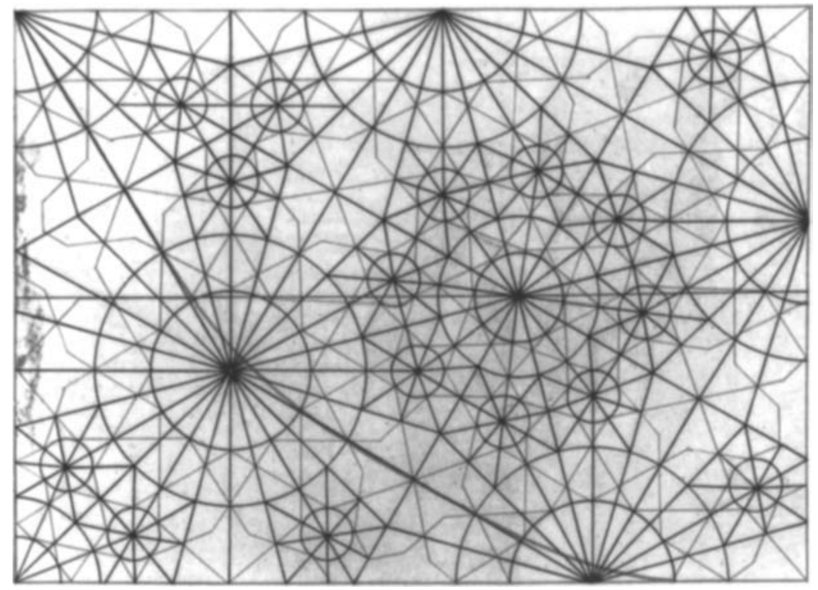
32.
Subject: Quarter repeat unit of a pattern with two superimposed layers, both of them based on five- and ten-pointed stars and polygons. The black-dotted grid gone over with solid orange lines grows from two ten-pointed quarter stars at the upper left and lower right corners; it defines polygons in contact with stars (rhomboids, irregular hexagons, and five-pointed stars). The points where these orange grid lines (created by joining the radii of uninked circles) intersect determine the centers of all the ten-pointed stars drawn in black ink and of some five-pointed stars. The black-ink pattern consists of ten- and five-pointed stars interlocking with polygons; each of its four corners is symmetrically occupied by ten-pointed quarter stars.
Dimensions: 25.5 × 35.5 cm.
Condition: Pasted toward the left edge; intact.
Technique: Uninked radial grid lines of concentric circles and arcs with ten and twenty radii surround each of the stars drawn in black ink. The dotted orange grid and black lines superimposed on it constitute two different layers of pattern. They could be used either jointly or separately. The uninked grid lines that generate the black-ink pattern consist of circles in contact with curved pentagons. Inside the two five-pointed stars defined by the orange grid are uninked concentric circles, each inscribed with a pentagon, that generate the paired five-pointed stars drawn in black ink. The composition is symmetrical along its central uninked horizontal axis (as well as its central vertical axis, which is not indicated among the uninked construction lines). The repeat unit is also symmetrical with respect to the various uninked oblique and diagonal axis lines intersecting at its center. Along one of these uninked axes the two paired five-pointed stars that stand out from others are aligned.



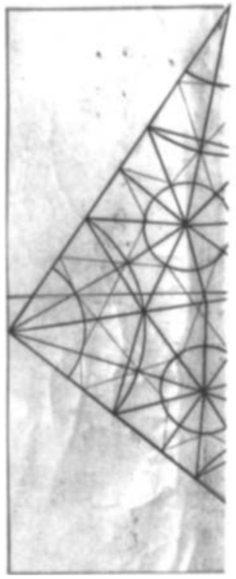
33.
Subject: Quarter repeat unit of a star-and-polygon pattern with two superimposed layers. The red-dotted grid lines define polygons in contact (quarter and half decagons, trapezoids, and an arrow-shaped six-sided polygon at the center) whose sides are bisected by two crossed black lines that meet to form the star-and-polygon pattern. The black-ink drawing grows out of two ten-pointed quarter stars at the upper corners and a ten-pointed half star at the center of the bottom edge. The extended lines of these large stars form an interlocking pattern of star fragments and polygons.
Dimensions: 25.7 × 25.5 (top), 25.3 cm (bottom).
Condition: Pasted near the left edge where the design has slipped slightly.
Technique: Uninked radial grid lines of concentric semicircles and quarter circles with nine and four radii, respectively, define the half and quarter stars that generate the black-ink pattern. These uninked radial grids are superimposed with red-dotted polygonal grid lines and the pattern in black ink. The repeat unit is bilaterally symmetrical with respect to its uninked vertical axis passing from the center of the composition. Two other uninked vertical lines complement the central vertical axis, subdividing the repeat unit into four equal strips. Another uninked horizontal line passes from the center of the composition.



34.
Subject: Quarter repeat unit of a pattern with two superimposed layers, both of them based on five- and ten-pointed stars and polygons. The black-dotted grid gone over in solid orange defines interlocking stars and polygons (five-pointed half stars, hexagons, and a ten-pointed composite polygon at the center). The intersection points of the orange grid lines formed by linking the radii of uninked circles determine the centers of all the ten-pointed stars drawn in black ink and of some five-pointed stars. The black-ink pattern, which grows from ten-pointed quarter stars at the upper right and lower left corners, consists of five- and ten-pointed stars interlocking with various polygons.
Dimensions: 25.8 × 25.8 cm.
Condition: Pasted along the right edge; intact.
Technique: Uninked radial grid lines of concentric circles and arcs with twenty and ten radii coincide with each of the stars drawn in black ink. Two uninked oblique axes of symmetry passing through the center of the repeat unit divide it into congruent parts. One of these oblique axes determines the centers of the two orange half stars along the upper and lower edge of the framing square. The two points where it intersects the outer frame of the repeat unit are accentuated by paired five-pointed half stars drawn in black ink. The other uninked oblique axis determines the centers of two orange half hexagons along the right and left edges of the repeat unit, bisecting the ten-pointed composite polygon aligned with it at the center of the composition. The repeat unit is also symmetrical with respect to the uninked horizontal and vertical axes intersecting at its center. The orange-dotted and black-ink lines superimposed on the uninked grid lines form two interrelated layers of pattern that could be used either jointly or separately. The pattern in black ink is generated by uninked decagons (inscribed in circles) in contact with pentagons, elongated hexagons, trapezoids, and rhombuses. At the center of the repeat unit the area defined by the orange ten-pointed composite polygon, which is surrounded by irregular hexagons, is filled with a black-ink pattern echoing the same composition twice (i.e., two ten-pointed composite polygons interlocking with irregular hexagons).

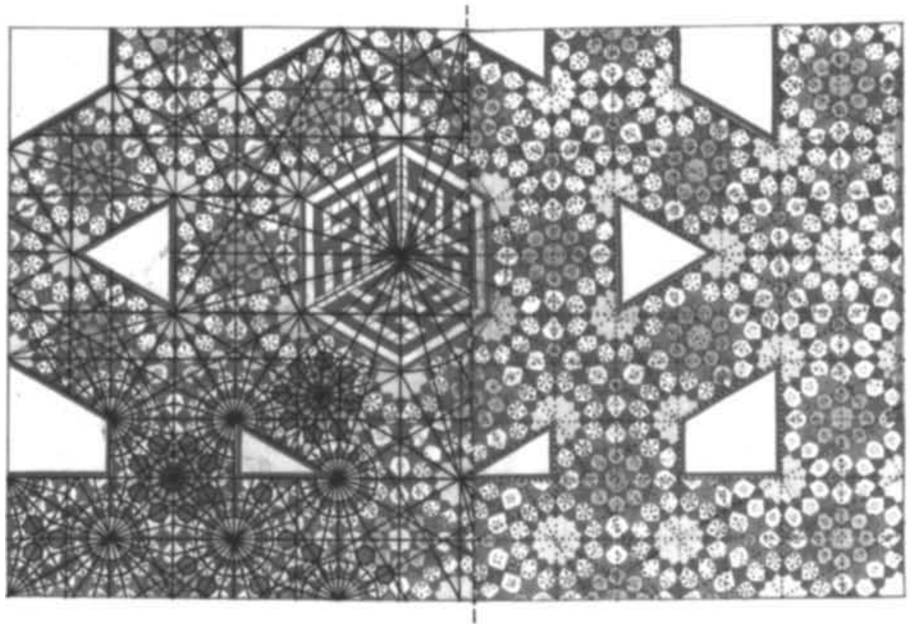


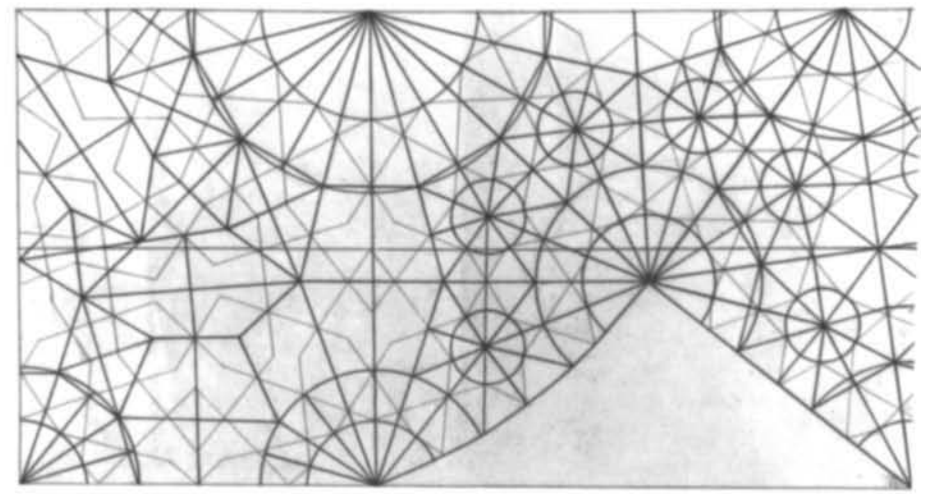
35.
Subject: Quarter repeat unit of a pattern with five-, eight-, and twelve-pointed stars interlocking with polygons and star fragments (including double bipeds facing each other and triple-armed polygons terminating with star fragments). A curved line (highlighted in a thick black-ink contour) passes through three of the twelve-pointed quarter, half, and full stars, dividing them unequally into five- and seven-pointed sections and at the same time bisecting the rhomboids and double bipeds facing each other along the same path. The curved line, which represents a pointed arch profile, suggests that the repeat unit was intended for arch spandrels and arched panels. It is closely related to cat. nos. 36 and 39, which constitute two fragmentary parts of a single repeat unit, also depicting a pointed arch profile with stars and polygons properly aligned or bisected along the curve of the arch. The geometric complexity of this pattern is exemplified by its use of three different types of stars; most of the two-dimensional star-and-polygon patterns in the scroll feature only one or two star types (except for cat. nos. 38, 39, and 44, all of which use three different types of stars). The star-and-polygon pattern of this repeat unit recurs in cat. no. 38.
Dimensions: 25.7 × 35.5 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric circles, semicircles, and quarter circles subdivided by twenty-four, sixteen, and ten radii, respectively, coincide with each of the stars drawn in black ink. The uninked construction lines include curved pentagons in contact with curved hexagons (double trapezoids) that surround the circles and arcs.



36.
Subject: Fragmentary pattern in a rotated square, the missing part of which appears later in the scroll as cat. no. 39, which depicts a star-and-polygon pattern with a pointed arch profile as in cat. no. 35. The two consecutive repeat units would have followed one another in the original order of the scroll. When joined with its missing component, cat. no. 35 forms a rotated square adjacent to an arch profile. Each of its corners is occupied by eight-pointed quarter stars that interlock with five-pointed stars, hexagons, and rhomboids. The center of the rotated square has an octagon.
Dimensions: Contained in a rectangular frame, 25.7 × 10.1 (top), 10.3 cm (bottom).
Condition: Pasted along the right edge. The missing side of this fragmentary design appears later in the scroll as cat. no. 39.
Technique: When the two parts of this design are joined together, its uninked radial grid lines become intact. They consist of concentric quarter circles at each corner of the square subdivided by three radii and inscribed with quarter octagons in contact with uninked pentagons containing circles with ten radii. At the center of the square frame uninked horizontal, vertical, and diagonal axes of symmetry intersect. The linear pattern is drawn in black ink.

37.
Subject: Repeat unit of a fragmentary square panel drawn on a squared grid composed of square kufic and geometric patterns. The square panel has an octagon around a central eight-pointed star formed by two rotating squares containing an inscription. It is accompanied by a linear strip of geometric patterning along the upper edge of the repeat unit. The linear strip contains a bilaterally symmetrical geometric repeat pattern.
Dimensions: 25.7 × 17 (top), 16.5 cm (bottom). Each square of the uninked squared grid measures 0.4 × 0.4 cm. The thick frame is 0.4 cm wide. Measuring from the interior of the frame along the right edge, the lower pattern is 17.5 cm high, and the top pattern is 6.5 cm high.
Condition: Pasted along the left edge. The left side is missing.
Technique: An uninked squared grid is incised on the paper in the form of dead lines, unlike most of the other squared grids of the scroll, which are gone over in black ink. The patterns generated by the grid are rendered in black ink. Although the linear strip pattern is bilaterally symmetrical, the square one possesses radial symmetry (except for its central inscription).
Inscription: Square kufic "Allāh" at the central rotated square.



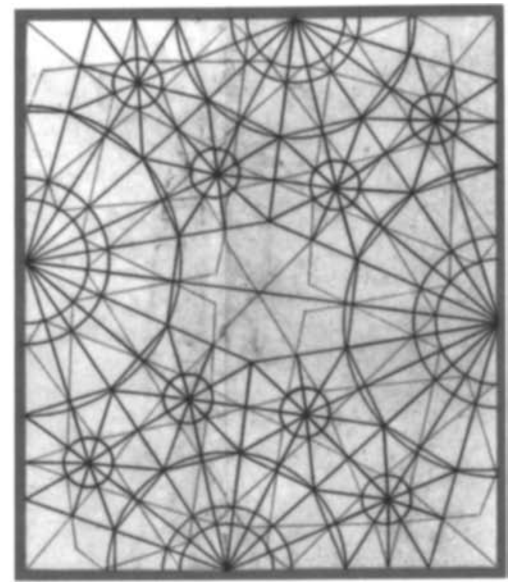


38.
Subject: Quarter repeat unit of a double-layered pattern for relief mosaic tile work with large polygonal shapes and a central calligraphic panel superimposed over a minute background pattern of interlocking stars and polygons. The square kufic inscriptions are framed by a hexagon composed of three interlocking rhombuses, creating an illusion of three-dimensionality. The repeat unit is surrounded by large triangles and quadrangles meant to be raised in low relief over the minutely patterned tile mosaic background. The corners of the large polygonal foreground units coincide with the centers of some twelve-pointed background stars. Moreover, if joined, these raised units would create a continuous field of tilings with no gaps. The minutely rendered background pattern is composed of five-, eight-, and twelve-pointed stars interlocking with polygons, a pattern that is a replica of cat. no. 35. Like cat. nos. 39 and 44 it uses three different star types. The intricacy and elaborate coloring of this pattern, by far the most labor intensive of all drawings included in the scroll, suggest that it was regarded as a tour de force deserving more decorative treatment. A comparable repeat unit for a relief mosaic tile pattern is cat. no. 49.
Dimensions: 25.7 × 40 (top), 40.5 cm (bottom).
Condition: Middle and right edge pasted. The design has slipped slightly at the middle part.
Technique: The multicolored pattern is generated by intricate uninked radial grid lines of concentric circles and arcs painstakingly subdivided by equidistant radii that generate the stars. The relief patterns outlined in thick black-ink lines are not colored. The thick outlines at the left and upper edges of the repeat unit were omitted because the pattern would be multiplied along those edges. When quadrupled, the repeat unit would create a symmetrical pattern with its center occupied by a hexagon and each of its four quarters featuring a central hexagonal calligraphic panel of the same size. Contained in three rhombuses subdivided into black-ink grids of smaller rhombuses, the inscriptions are rendered in red. The background pattern is differentiated from the rest by its elaborate color coding. Light blue, gray, pink, orange, yellow, and black are used in addition to the creamy color of the paper to indicate the symmetrical properties of the pattern that would be executed in mosaic tile work of different colors. Each color marks a specific shape; light blue is used for the twelve-pointed stars, orange for the five-pointed stars, and gray for the eight-pointed stars. Some of the units have tiny rosettes, suggesting that they were meant to be executed in patterned mosaic tiles. Since this repeat unit is painted over in colors, its indented uninked grid lines are only faintly visible. Hence, the overlay only partially indicates the minute crisscross construction lines that repeat the scheme of cat. no. 35. The design is radially symmetrical around an uninked central circle with twenty-four radii that pass through twelve-pointed star centers aligned along an orthogonal grid of vertical, horizontal, and diagonal lines.
Inscriptions: Square kufic in red, the word repeated three times is undeciphered. Although two of the rhombuses contain identical inscriptions, the third one has a different first letter, probably a mistake.

39.
Subject: Repeat unit of a star-and-polygon pattern with five-, eight-, and twelve-pointed stars interlocking with polygons and star fragments, including overlapping double bipeds, double trapezoids in the shape of bow ties, and ten-pointed composite polygons. A curved line representing the profile of a pointed arch passes through the centers of three eight-pointed stars, bisecting at the same time the hexagons placed along the same path. Like cat. no. 35, which also features a curved arch profile, this is a pattern intended for an arched panel. It forms a single repeat unit with cat. no. 36 and would have followed cat. no. 35 in the original order of the scroll. Unlike cat. no. 35, where the star-and-polygon pattern fills the arch spandrel, here a pattern framed by a rotated square is provided (the missing part is included in cat. no. 36). The composition in the rotated square has five- and eight-pointed stars, unlike the one framed by the arch profile where three different star types are used.
Dimensions: 25.7 × 48.5 cm. The size of the arched panel along the top edge is 44.7 cm; along the bottom edge it is 19.9 cm. The sides of the rotated square measure approximately 18 cm.
Condition: Pasted along both ends. The remainder of the fragmentary right part appears in cat. no. 36.
Technique: Uninked radial grid lines of concentric arcs and small circles subdivided by equidistant radii generate the five-, eight-, and twelve-pointed stars in black ink. Inside the large circles are inscribed uninked polygons; the extended radii of these large circles define curved pentagons containing the five-pointed stars drawn in black ink. The left half of the repeat unit is dominated by uninked polygons, including rhombuses and elongated hexagons. The star-and-polygon pattern generated by these uninked construction lines is rendered in black ink. The uninked grid system of the geometrically related pattern framed by the rotated square is described in cat. no. 36.

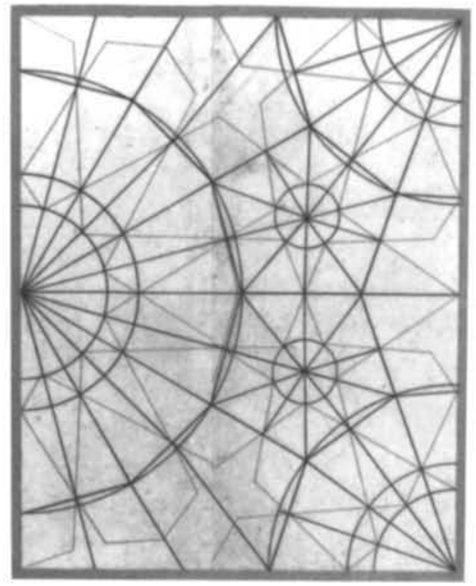
40.
Subject: Linear repeat unit of a square kufic inscription contained in a cartouche with fragments of eight-pointed stars at each end; it is drawn on a squared grid.
Dimensions: 24.5 × 8.3 cm. The squares of the grid measure 0.4 × 0.4 cm.
Condition: Pasted along the left edge; intact. The thick frame (approximately 0.4 cm wide) of the scroll starts here. The only thick-framed repeat unit preceding this one is cat. no. 37.
Technique: Both the squared grid and the bilaterally symmetrical geometric pattern, vertically extendable at both ends, are rendered in black ink.
Inscription: Square kufic "Subḥān Allāh wa a," meant to be continued as "al-ḥamd li'llāh" (Praise be to God and thanks to God!).

41.
Subject: Repeat unit composed of rotated squares and rhombuses with kufic calligraphy. The calligraphic panels alternate with rotated squares containing swastikas that are attached to triangles forming four-pointed stars.
Dimensions: 24.5 × 24.5 cm. The small squares and rhombuses of the grids measure 0.4 × 0.4 cm.
Condition: Fine.
Technique: The kufic inscriptions are based on square- and rhombus-shaped grids outlined in black ink. The rest of the pattern is also rendered in black ink. The swastikas are framed by uninked rotated squares, some of which are subdivided into sixteen smaller uninked squares (0.8 × 0.8 cm) guiding the outlines of the swastikas contained in them. The whole composition is divided into four equal quadrants by two uninked vertical and horizontal axes that pass from its center. No other construction lines are indicated.
Inscriptions: Square kufic in black "Allāhu" at the central rhombus (and the four half rhombuses along the edges of the repeat unit), surrounded by four rotated squares inscribed "Akbar" and meant to be read together as "Allāhu Akbar" (God is Great).

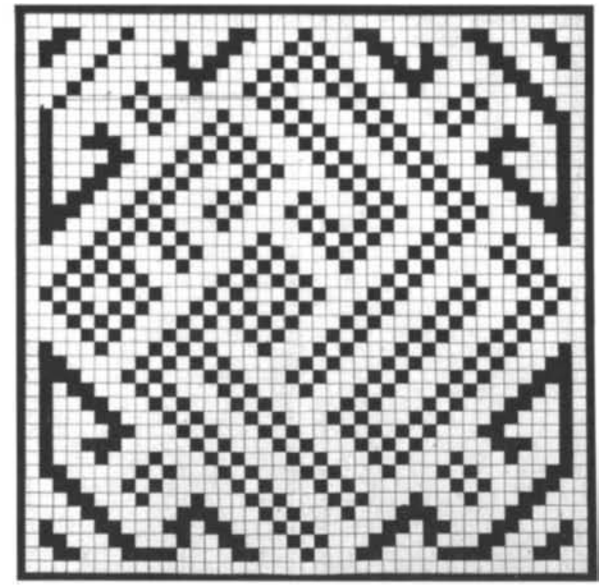


42.
Subject: Repeat unit of a star-and-polygon pattern without dotted or solid grid lines, in which the composition is oriented along two oblique axes of symmetry that intersect at the center of the composition and divide the repeat unit into four congruent parts. Along these axes are aligned a pair of double bipeds and hexagons interlocking at the center of the composition. The points at which the two oblique axes intersect the frame of the repeat unit determine the centers of four half stars. Those along the upper and bottom edges are nine-pointed half stars; the other pair along the lateral edges are eleven-pointed half stars. Extending the lines of these stars generates a pattern composed of smaller five-pointed stars interlocking with polygons.
Dimensions: 24.5 × 21 cm.
Condition: Pasted toward the middle where the design has slipped slightly.
Technique: Uninked radial grid lines of concentric semicircles subdivided by eight and ten radii, respectively, generate the four half stars along the edges. Their extended radii form uninked pentagons in contact and a central elongated hexagon aligned with the two uninked oblique axes of symmetry that intersect at the center of the repeat unit (their point of intersection is not indicated). The pattern generated by the uninked construction lines is rendered in black ink.

43.
Subject: Geometric panel based on a squared grid, composed of a central star octagon containing a square kufic inscription, formed by two rotated squares and surrounded by pentagons. The four corners of the repeat unit are occupied by eight-pointed quarter stars.
Dimensions: 24.5 × 24.5 cm. The squares of the inked grid measure 0.5 × 0.5 cm.
Condition: Fine.
Technique: Both the squared grid and the geometric pattern generated by it are rendered in black ink. A few uninked construction lines guide the composition (parallel lines that extend the sides of the central rotated squares until they meet the outer frame, cutting off a triangle at each corner).
Inscription: Square kufic "Allāh" in the center.

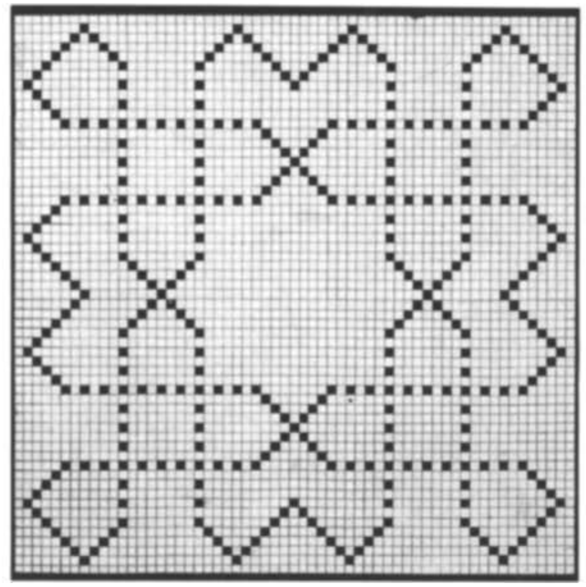


44.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The lines of the solid red grid of polygons in contact (pentagons, a half dodecagon, and quarter decagons) are bisected by two crossing lines that generate the pattern rendered in black ink. The latter is composed of five-, ten-, and twelve-pointed stars, polygons, and triple-armed polygons terminating with star fragments. Like cat. nos. 35, 38, and 39, it is composed of three different star types.
Dimensions: 24.5 × 19.5 (top), 19.3 cm (bottom).
Condition: Pasted toward the middle where the design has slipped slightly.
Technique: Uninked radial grid lines of concentric quarter circles, with four radii each, at the upper and lower right corners and larger concentric semicircles, with eleven radii, along the left edge generate the large stars. Their extended radii define the contours of uninked pentagons that contain the smaller five-pointed stars drawn in black ink. The design is bilaterally symmetrical along an uninked horizontal axis of symmetry passing through its center.

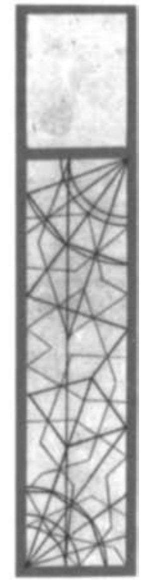


45.
Subject: Square kufic calligraphic panel based on a squared grid; the inscription is contained in a rotated central square whose corners touch the midpoints of the repeat unit's edges. The triangles formed at each of the four corners are filled with geometric patterns.
Dimensions: 24.5 × 24.5 cm. The squares of the inked grid measure 0.5 × 0.5 cm.
Condition: Fine. Error on the sixth horizontal grid line from the top. The geometric design at the upper left corner is incomplete.
Technique: The rotated central square is delineated with uninked construction lines. Two uninked horizontal and vertical axes intersect at the center of the composition. Both the squared grid and the patterns generated by it are rendered in black ink. The pattern was first marked on the grid squares by indented points made by a compass.
Inscription: Square kufic "Man kāna li'llāh" (I belong to God).

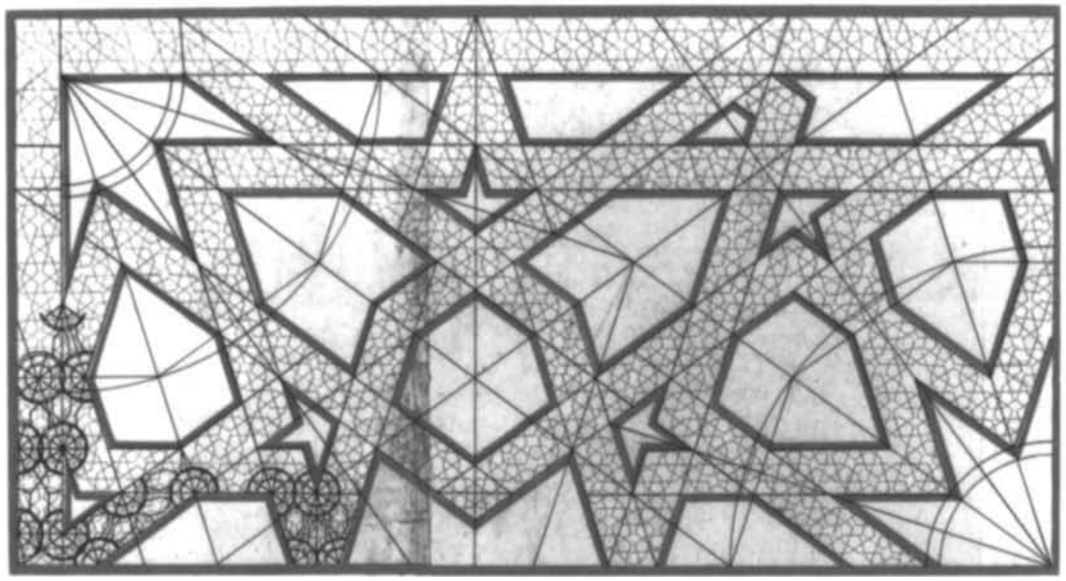
46.
Subject: Repeat unit of a star-and-polygon pattern without dotted or solid grid lines, composed of a pair of six-pointed quarter stars at the upper right and lower left corners that interlock with double pentagons and other polygons.
Dimensions: 24.5 × 7.8 cm.
Condition: Fine. A line at the upper left corner, which would have made the drawing symmetrical, is missing.
Technique: Uninked radial grid lines of concentric quarter circles appear at the upper right and lower left corners; they are each subdivided by five radii that extend up to an uninked oblique axis of symmetry that bisects the central double pentagons, cutting the repeat unit into two congruent parts.

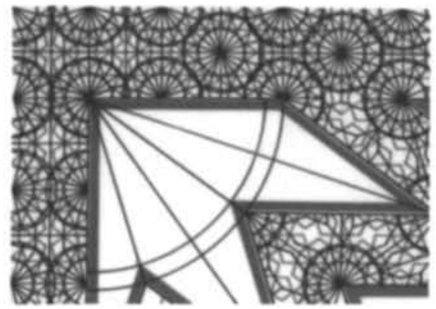


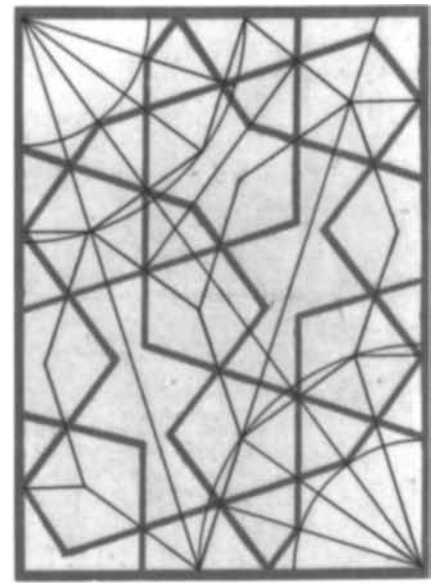
47.
Subject: Geometric pattern based on a squared grid, composed of a central eight-pointed star formed by two rotated squares and interlocked with pentagons, squares, and ten-pointed composite polygonal shapes (combining two pentagons and a rotated square).
Dimensions: 24.5 × 24.5 cm. The squares of the inked grid measure 0.4 × 0.4 cm.
Condition: Pasted along the left edge; intact.
Technique: An uninked orthogonal grid of squares and rectangles regulates the pattern. Both the squared grid and the geometric design superimposed on it are rendered in black ink. The squares filled in with black ink were first marked as indented points made by the point of a compass.



48.
Subject: Repeat unit of a star-and-polygon pattern with two layers. The red-dotted grid lines define polygons in contact whose sides are bisected by two crossing lines that meet to form the asymmetrically composed main pattern drawn in black ink. The red-dotted grid lines are also trisected at one point by two pairs of crossing lines forming a rhombus at the intersection of two overlapping arrow-shaped polygons. The pattern in black ink grows from two quarter stars of unequal size (eight- and ten-pointed) occupying the upper right and lower left corners.
Dimensions: Contained in a larger frame, 25.5 × 4.5 cm. The repeat unit measures 18 × 4.5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles, each with four radii, appear at the two corners occupied with quarter stars. An uninked vertical line passing from the center cuts the asymmetrical pattern. Other uninked construction lines divide the repeat unit into congruent parts that frame the polygonal shapes drawn in black ink. The red-dotted grid and the pattern in black ink constitute two layers superimposed on the uninked dead lines.



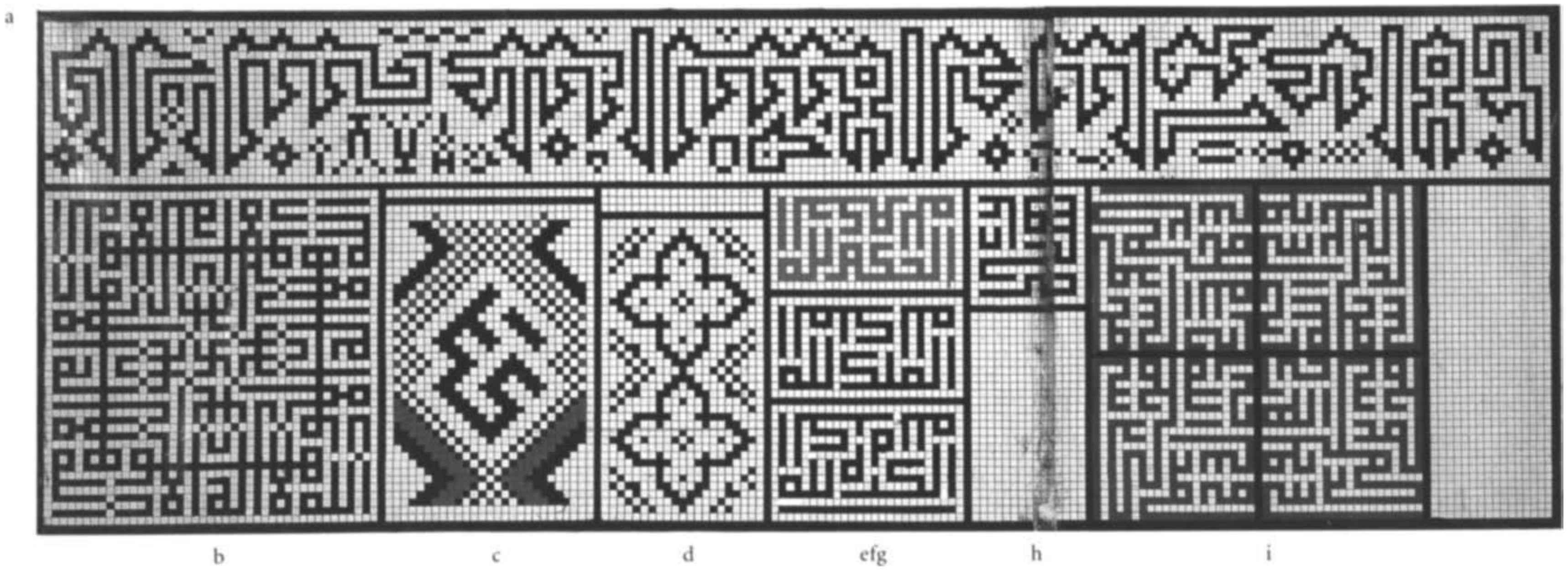




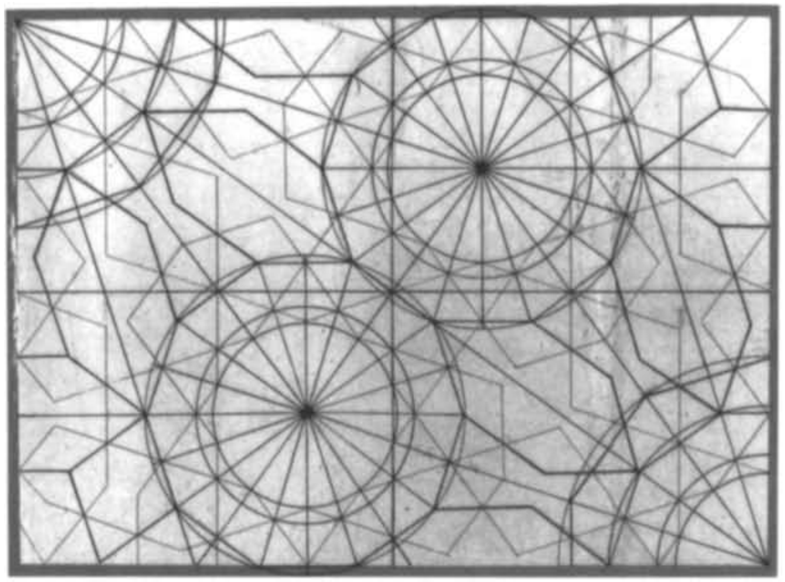
49.
Subject: Quarter repeat unit of a double-layered pattern for relief mosaic tile work (as in cat. no. 38). When quadrupled, the thickly outlined large polygons and star fragments raised in relief would form a composition with a central ten-pointed star, and four ten-pointed quarter stars at each corner of the frame. Joining the large polygonal shapes, whose corners coincide with the centers of some smaller stars of the background pattern, would form a continuous field of tilings with no gaps. The minutely rendered background pattern, drawn in thin black-ink outlines, is composed of ten-pointed stars interlocking with various polygons.
Dimensions: 24.5 × 46.5 cm.
Condition: Pasted toward the middle; intact.
Technique: Uninked radial grid lines of concentric quarter circles, subdivided by four radii, coincide with the quarter stars at the upper left and lower right corners. These guide the distribution of the large polygonal shapes, complemented by multiple uninked parallel diagonal, vertical, and horizontal lines that crisscross the surface and coincide with some of the thick outlines of the large polygonal shapes. It was not possible to record all of the lines along which the centers of background ten-pointed stars are aligned. The small-scale background pattern (see overlay 49a) is generated by intricate uninked circles inscribed with decagons, subdivided by twenty radii, in contact with elongated hexagons and double trapezoids in the shape of bow ties. The thick borders of the large polygons are omitted on the bottom and right edges along which the repeat unit would be multiplied.

49a

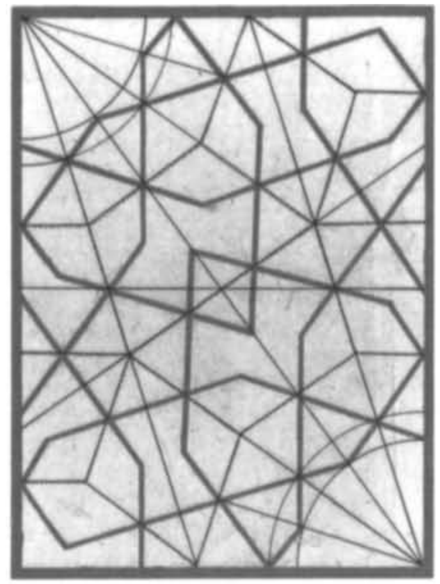
50.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid defines polygons in contact (quarter decagons, elongated hexagons, and double trapezoids in the shape of bow ties) whose sides are bisected by pairs of crossing lines that meet to form a pattern rendered in thick black-ink outlines. This pattern grows from two ten-pointed quarter stars at the upper left and lower right corners, whose extended lines form interlocking polygons. This is a variant of cat. no. 52.
Dimensions: 24.5 × 17.5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles, with four radii each, coincide with the corner stars. All the red-dotted grid lines and the parallel boundaries of the thick lines are indented on the paper. Two uninked oblique axes of symmetry forming a V shape (one of them coinciding with the first radius of the upper left corner) bisect the two elongated hexagons of the red-dotted grid (as well as the polygonal shapes drawn in black ink along the same axes).



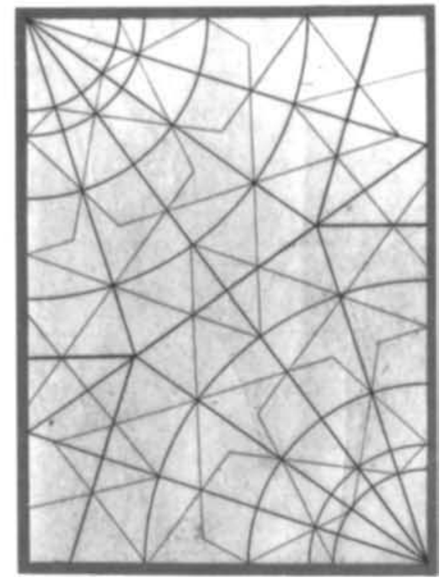
51.
Subject: (a) Strip of a naskhi inscription for *bannā'ī* brick masonry, based on a squared grid and accompanied by geometric filler patterns along the edges.
Dimensions: Contained in a rectangular frame together with cat. nos. 51b–i, 73 × 24.5 cm. Cat. no. 51a measures 7.8 × 73 cm. The squares of the inked grid measure 0.3 × 0.3 cm.
Condition: Pasted near the middle; intact.
Technique: Both the squared grid and the inscription superimposed on it are rendered in black ink. The inked squares were first marked by black dots; those marking the wrong squares were corrected with white paint.
Inscription: The hadith "Qāl al-nabī ʿalayhi al-salām al-dunyā mazraʿat al-ākhirat" (The Prophet, on Him be peace, said, "The world is a sowing field for the other world" [i.e., You shall reap what you sow]).
Subject: (b) Square kufic calligraphic panel with a swastika in the center based on a squared grid.
Dimensions: 16 × 16 cm.
Condition: Fine.
Technique: Both the squared grid and the inscriptions are rendered in black ink.
Inscriptions: "Lā ilāha illā' llāh" (There is no God but God) and "huwa" (He [a name of God]), rotated four times, once in each quadrant of the square frame.
Subject: (c) Linear repeat unit of a square kufic inscription contained in a geometric pattern of two superimposed rotated squares, based on a squared grid.
Dimensions: 15.8 × 10 cm.
Condition: Fine.
Technique: The squared grid lines are drawn in black ink, while the pattern itself is rendered in black and pinkish red ink. The upper and lower halves of the geometric pattern are colored differently to show two possible options for the ordering of glazed bricks.
Inscription: "Akbar" (Great), meant to be accompanied by "Allāhu" to complete the phrase "Allāhu Akbar" (God is Great).
Subject: (d) Linear repeat unit of geometric pattern based on a squared grid, consisting of four-petaled rosettes framed by rotated squares cut off at the corners.
Dimensions: 14.5 × 7.8 cm.
Condition: Fine. The design at the lower right corner is inaccurate. There is also a redundant line along the twelfth horizontal line from the bottom edge of the grid.
Technique: Both the squared grid and the bilaterally symmetrical geometric pattern generated by it are rendered in black ink.
Subject: (e) Rectangular square kufic calligraphic panel on a squared grid.
Dimensions: 5 × 9.3 cm.
Condition: Fine.
Technique: The inscription is rendered in orange over the squared grid drawn in black ink.
Inscriptions: "Al-ḥukm li'llāh" (Authority is God's), repeated twice.
Subject: (f) Rectangular square kufic calligraphic panel on a squared grid.
Dimensions: 5 × 9.3 cm.
Condition: Fine.
Technique: Both the squared grid and the inscription are rendered in black ink.
Inscriptions: "Al-mulk li'llāh" (Sovereignty is God's), repeated twice.
Subject: (g) Rectangular square kufic calligraphic panel on a squared grid.
Dimensions: 5.3 × 9.3 cm.
Condition: Fine.
Technique: Both the squared grid and inscription are rendered in black ink. Mistakes were corrected with white paint.
Inscriptions: "Al-karam li'llāh" (Generosity is God's), repeated twice.
Subject: (h) Square kufic calligraphic panel on a squared grid.
Dimensions: 5.5 × 5.5 cm.
Condition: Pasted in the middle; intact.
Technique: Both the squared grid and the inscription are rendered in black ink.
Inscription: Undeciphered.
Subject: (i) Square kufic calligraphic panel on a squared grid, contained in a square frame divided into four equal quadrants with a central swastika.
Dimensions: 16 × 16 cm.
Condition: Fine. Redundant line along the fourth horizontal line from the top of the grid.
Technique: The red-ink inscriptions are superimposed on the squared grid drawn in black ink; the two horizontal and vertical axes dividing the panel into four equal quadrants are also indicated in thick black-ink outlines (0.3 cm).
Inscriptions: "Muḥammad Nabiyyu Allāh" (Muhammad is the Prophet of God), repeated twice in each quadrant.



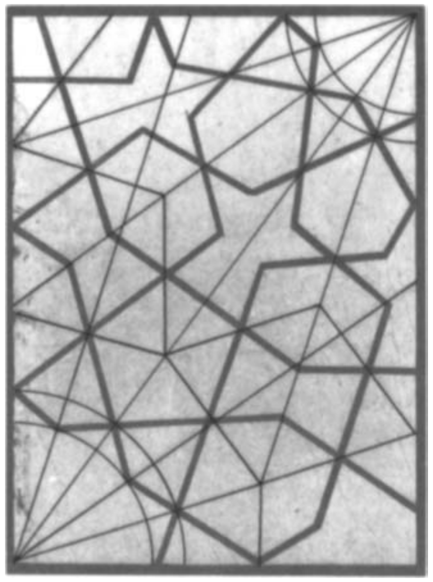
52.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The lines of the red-dotted grid of polygons in contact (quarter and full decagons, elongated hexagons, rhombuses, and double trapezoids in the shape of bow ties) are bisected by pairs of crossed lines in black ink that intersect to form the main pattern. The black-ink pattern is composed of ten-pointed stars interlocking with pentagons and other polygons; there are two ten-pointed quarter stars at the lower right and upper left corners. This is a variant of cat. no. 50.
Dimensions: 24.5 × 33.8 (top), 33.5 cm (bottom).
Condition: Pasted toward the right edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles and circles with four and twenty radii, respectively, coincide with the stars. Two uninked oblique axes of symmetry intersect at the center of the repeat unit; one of them is the diagonal connecting the upper left and lower right corners occupied by quarter stars, the other passes through the centers of the two ten-pointed stars. Together with the uninked horizontal and vertical axes passing through the center, they divide the composition into congruent parts. These uninked construction lines are superimposed with red-dotted grid lines defining polygons in contact and the pattern in black ink.



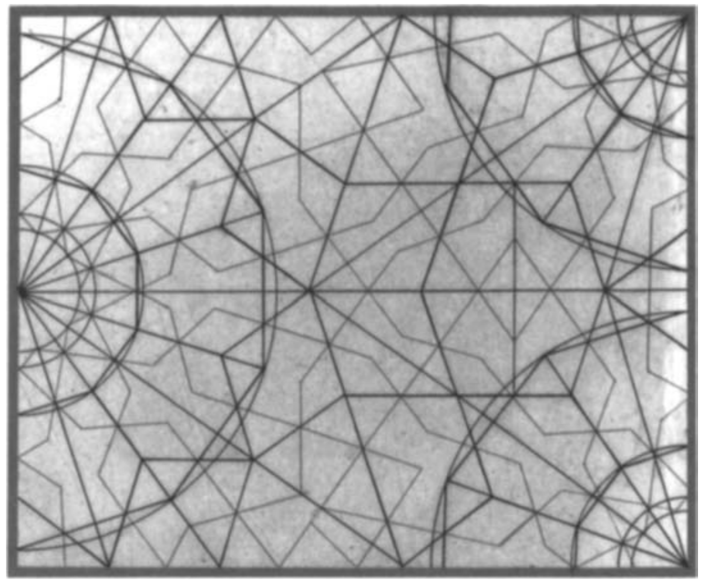
53.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines form polygons in contact (quarter decagons, trapezoids, and rhombuses) whose sides are bisected by two crossing thick black-ink lines. The red-dotted line passing from the center of the composition, however, is trisected by two pairs of crossing lines forming a central rhombus at the intersection of two overlapping double bipeds. The pattern in thick black ink is composed of interlocking polygons growing from two ten-pointed quarter stars at the upper left and lower right corners. This is a variant of cat. no. 72d, which also has two overlapping double bipeds interlocking with a pair of pentagons at the center. It is also a variant of the next repeat unit (cat. no. 54) featuring a similar dotted grid line that passes from the center of the composition and is trisected by two pairs of crossing lines forming a central rhombus.
Dimensions: 24.5 × 18 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles, each with four radii, appear at the two corners occupied by stars. The diagonal connecting these corners and two radii emanating from each of the corner stars form an N shape constituting three axes of symmetry along which the polygonal shapes of the black-ink pattern are aligned. An oblique axis of symmetry also passes through the center of the repeat unit, dividing it into congruent halves. These uninked axes of symmetry that guide the composition are complemented by an uninked horizontal line passing through some important points.



54.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid divides the frame into four polygonal parts. The grid lines are trisected by two pairs of crossing lines in black ink that meet to form the main pattern. The black-ink pattern is composed of two ten-pointed quarter stars at the upper left and lower right corners whose extended lines form interlocking polygons. The center of the composition has a rhombus created by two overlapping rhomboids that interlock with a pair of pentagons. The red-dotted grid line passing from the center is trisected by two pairs of crossing lines forming that rhombus, as in cat. no. 53.
Dimensions: 24.5 × 18 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles, each with four radii, appear at the two corners occupied by stars. An uninked oblique axis of symmetry intersects at the center of the composition with the diagonal axis of symmetry connecting the two starred corners, cutting the repeat unit into four congruent parts.

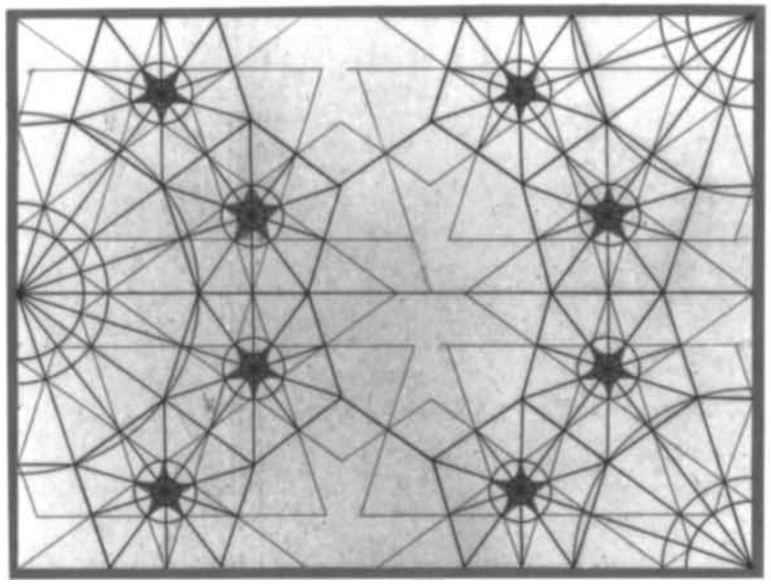


55.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The black-dotted grid lines form polygons in contact (a ten-pointed quarter star at the upper right corner, rhombuses, and a quarter decagon at the lower left corner). These dotted grid lines are bisected by two crossing thick red lines (filling two parallel lines in black ink). The red-ink pattern, growing from two ten-pointed quarter stars of different sizes at the upper right and lower left corners, is composed of interlocking polygons and star fragments.
Dimensions: 24.5 × 18 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles, each with four radii, coincide with the two quarter stars at diagonal corners. The four radii emanating from the upper right corner extend the whole length of the repeat unit, bisecting the polygons lined up along them. The two parts of the repeat unit that are clustered around each of the quarter stars form completely asymmetrical compositions separated by a quarter decagon drawn in thick red-ink lines. The area at the upper right corner delineated by that quarter decagon has interlocking hexagons and nine-pointed composite polygons (combining a trapezoid and a star fragment). The rest of the repeat unit has a different type of polygonal pattern in which pentagons interlock with double trapezoids in the shape of bow ties. (For a similar composition see cat. nos. 48 and 56.) The repeat unit is cut into two congruent triangles by an uninked diagonal axis of symmetry joining the upper right and lower left corners.

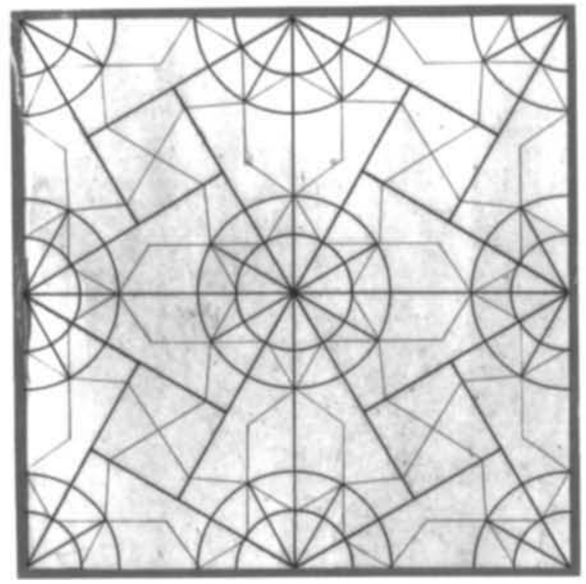


56.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The solid red grid lines form polygons in contact (quarter and half decagons, pentagons, rhombuses, rhomboids, and trapezoids) whose sides are bisected by two crossing black-ink lines that meet to form a star-and-polygon pattern. Some of the polygonal grid lines are trisected by pairs of crossing black-ink lines that delineate overlapping arrow-shaped polygons whose intersection forms a rhombus. The pattern drawn in black ink grows from two ten-pointed quarter stars at the upper and lower right corners and a ten-pointed half star along the left edge. These quarter and half stars are each surrounded by pairs of parallel quarter and half decagons drawn in black ink that mark areas filled with different types of polygons (hexagons interlocking with nine-pointed composite polygons combining a trapezoid and a star fragment). Areas falling beyond them have a different polygonal pattern. (For a similar composition see cat. nos. 48 and 55.)
Dimensions: 24.5 × 30 cm.
Condition: Pasted along the right edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles and semicircles with four and nine radii, respectively, coincide with the two quarter stars and half star, as well as the quarter and half decagons that surround them at a distance. These construction lines are accompanied by an uninked horizontal axis of symmetry that passes through the center of the bilaterally symmetrical composition. Alternating radii emanating from the upper and lower right corners intersect the horizontal axis at a point coinciding with the center of a pentagon drawn in black ink. The composition is radially symmetrical along several axis lines that converge at the center of that pentagon.

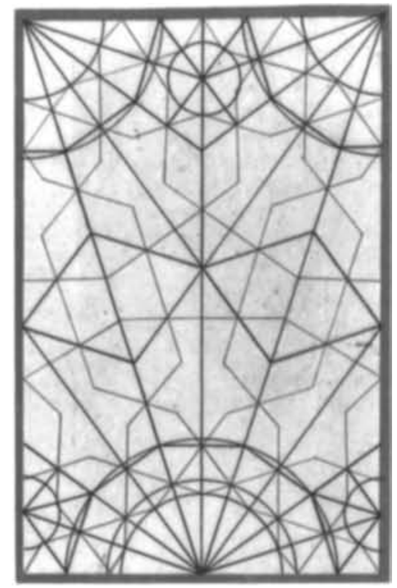
57.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines divide the repeat unit into polygons in contact whose sides are bisected by pairs of crossing thick lines in black ink. The thickly outlined main pattern grows from two eight-pointed quarter stars at the upper left and lower right corners that interlock with polygons; its center has a composite polygon with star fragments at both ends.
Dimensions: 24.5 × 10 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with three radii each, appear at the upper left and lower right corners. Along the right and left edges uninked semicircles generate star fragments and half octagons. The center of each is determined by the points at which the radii of the quarter stars in diagonal corners intersect with the outer frame. The repeat unit is cut into congruent parts by two axes of symmetry that intersect at the center of the composition. One of these is the uninked diagonal that joins the two starred corners and the other one (unindicated in the repeat unit) is an oblique axis passing through the centers of the half octagons along the lateral edges. These are complemented by a third uninked horizontal line that bisects the repeat unit into two symmetrical halves.



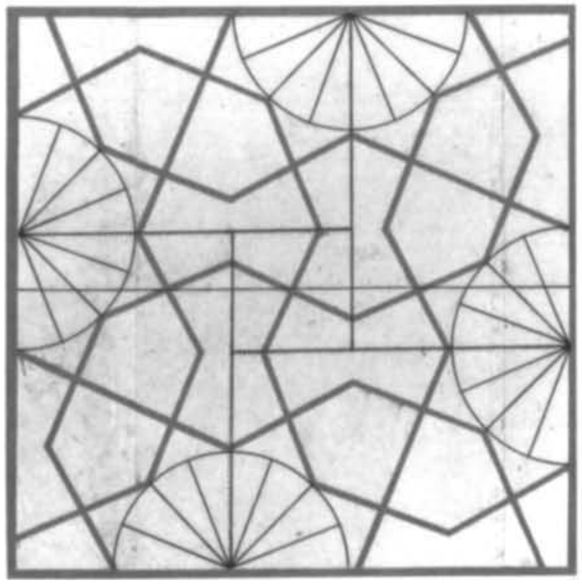
58.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines form polygons in contact (pentagons, quarter and half decagons, and half and full elongated octagons) whose sides are bisected by pairs of crossing black-ink lines that meet to form the main pattern. The design in black ink grows from ten-pointed quarter stars along the upper and lower right corners and a ten-pointed half star along the left edge. It is composed of five-pointed stars (containing smaller red five-pointed stars, probably denoting inset plaques) that interlock with various polygons and an irregular eight-pointed star at the center.
Dimensions: 24.5 × 32.7 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles and semicircles with four and nine radii, respectively, coincide with the ten-pointed quarter and half stars (and the red-dotted quarter and half decagons surrounding the stars). The five-pointed stars contained in dotted pentagons are generated by small uninked concentric circles with ten radii. An uninked horizontal axis of symmetry passes through the center of the composition, bisecting it into two symmetrical halves.



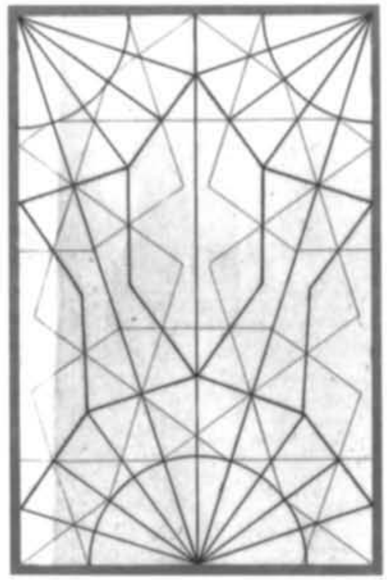
59.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines define four rotated squares in each quadrant. The four prolonged sides of each square join at the center and sides of the repeat unit, forming a red-dotted grid of congruent triangles and kite-shaped rhomboids in contact with four rotated squares. The points at which the prolonged sides of the rotated squares intersect the outer frame of the repeat unit determine the centers of the six-pointed quarter and half stars drawn in black ink at the corners and along the edges of the repeat unit. The red-dotted grid lines meeting at the middle of the composition determine the center of a six-pointed star. The stellate pattern in black ink is composed of interlocking polygons with each rotated square grid containing swastika-like forms.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric circles and arcs with two, five, and twelve radii, respectively, coincide with the quarter, half, and full stars. Two uninked horizontal and vertical axes of symmetry intersecting at the center divide the repeat unit into four equal quadrants. The red-dotted grid of polygons in contact probably would be eliminated from the final pattern.



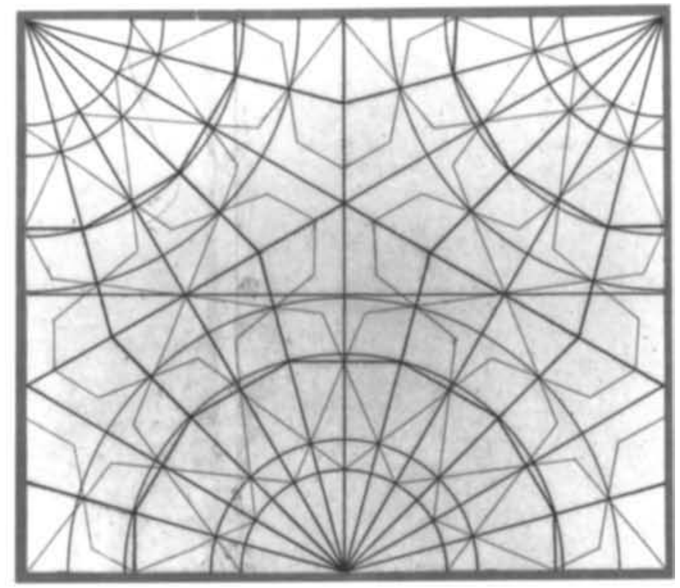
60.
Subject: Quarter repeat unit of a star-and-polygon pattern with two layers. The red-dotted grid lines define polygons in contact (pentagons, rhombuses, and quarter and half decagons) whose sides are bisected by the crossing black lines of the main pattern. The black-ink pattern grows from two ten-pointed quarter stars at the upper corners and a ten-pointed half star along the bottom edge. It is composed of interlocking polygons, five-pointed stars, and star fragments.
Dimensions: 24.5 × 15.8 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles and semicircles with four and nine radii, respectively, coincide with the ten-pointed quarter and half stars. Small uninked circles with ten radii, inscribed in dotted pentagons, generate the five-pointed stars. These uninked construction lines are accompanied by an uninked vertical axis of symmetry that passes through the center of the composition, bisecting it into bilaterally symmetrical halves. The two radii of the upper corners that extend up to the midpoint of the bottom edge and form a V shape also constitute uninked axes of symmetry along which design elements are aligned.



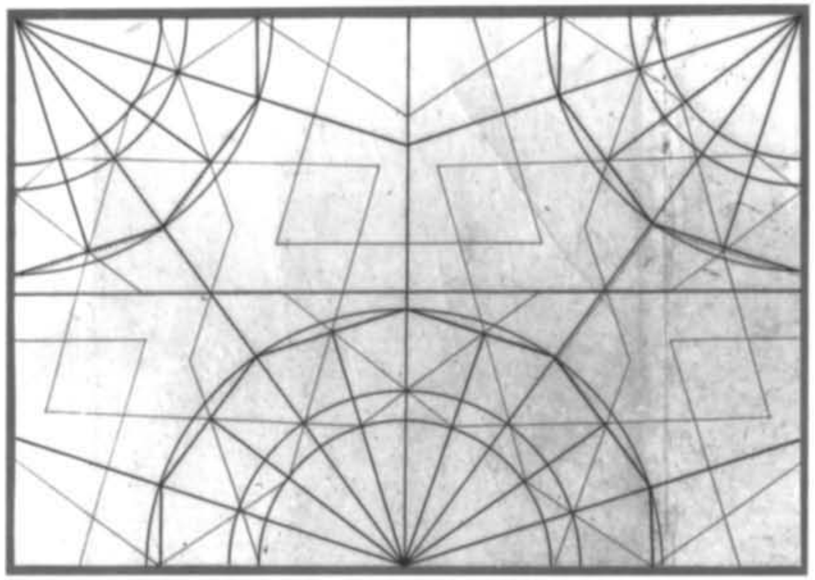
61.
Subject: Repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid defines a central square with four extended sides that divide the repeat unit into four rectangles. The points where the extended sides of the dotted central square meet the outer frame determine the centers of four eight-pointed half stars, one along each edge of the repeat unit. These stars, drawn in thick black-ink lines, interlock with pentagons, double pentagons, and a swastika-like form framed by the central red-dotted square.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted near both ends; intact.
Technique: Uninked radial grid lines of four semicircles, each with seven radii, generate the half stars. These construction lines are accompanied by the red-dotted grid that would have been eliminated from the final pattern. An uninked horizontal construction line passes through the center of the composition, determining the midpoint of the swastika-like form.



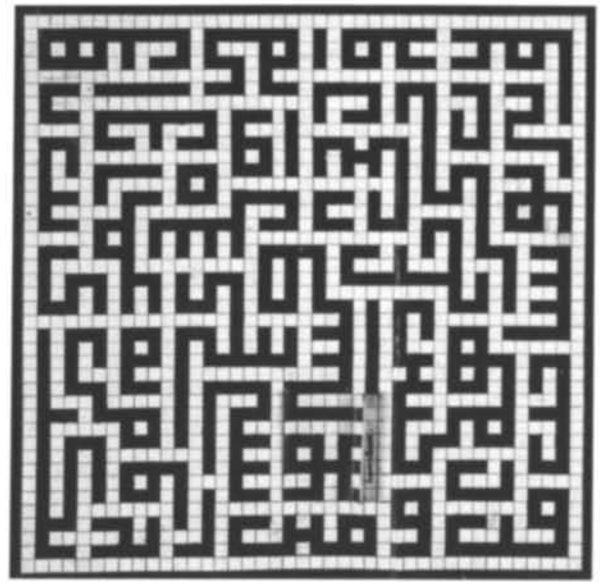
62.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines define polygons in contact (quarter and half decagons, elongated hexagons, and double trapezoids in the shape of bow ties) whose sides are bisected by the crossing lines of the pattern in black ink. The pattern grows from two ten-pointed quarter stars at the upper corners and a ten-pointed half star along the bottom edge, which interlock with various polygons.
Dimensions: 24.5 × 16 cm.
Condition: Fine.
Technique: Uninked radial grid lines consist of two quarter circles and a semicircle with four and nine radii, respectively, that generate the quarter and half stars. An uninked vertical axis of symmetry passing through the center bisects the repeat unit into bilaterally symmetrical halves. The first radii of the upper corners, which join to form a V shape at the center of the bottom edge, also constitute axes of symmetry along which design elements are aligned.



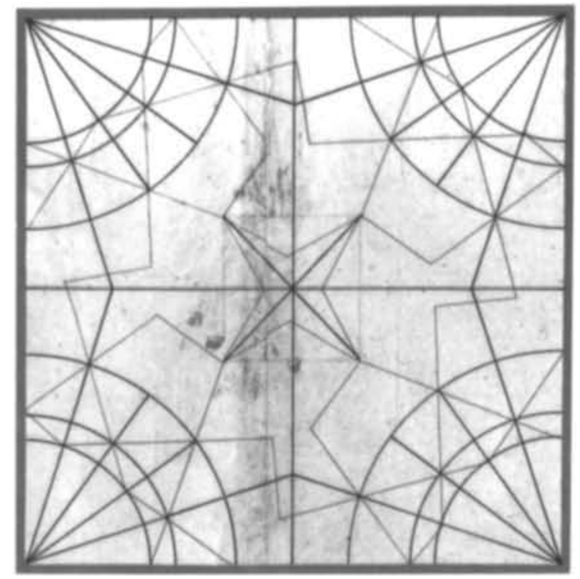
63.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines define polygons in contact (pentagons, trapezoids, and quarter and half dodecagons) whose sides are bisected by pairs of crossing lines forming the pattern in black ink. The pattern grows from two twelve-pointed quarter stars at the upper corners and a twelve-pointed half star along the bottom edge, which interlock with polygons, double bipeds, and triple-armed composite polygons with star fragments.
Dimensions: 24.5 × 28.5 cm.
Condition: Pasted near the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles and semicircles with five and eleven radii, respectively, generate the stars at the two upper corners and along the bottom edge. These radii extend up to three red-dotted grid lines, constituting axes of symmetry, that intersect at the midpoint of the triple-armed composite polygon with star fragments. The latter is bisected by an uninked vertical axis of symmetry passing through the center of the bilaterally symmetrical composition. An uninked horizontal line crossing the midpoint of the repeat unit coincides with some important points. The two radii of the upper corners, which extend to the midpoint of the bottom edge and form a V shape, also constitute uninked axes of symmetry along which design elements are aligned. Two other uninked axes of symmetry are the radii of the upper corners that extend up to the lateral edges of the repeat unit, intersecting at the central vertical axis of symmetry.



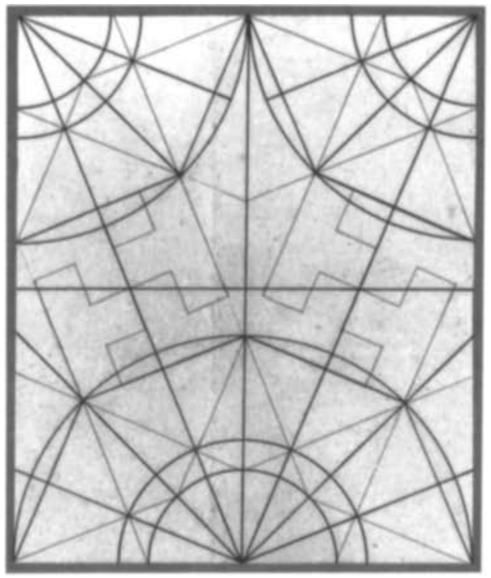
64.
Subject: Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines define polygons in contact (pentagons and quarter and half decagons) whose sides are bisected by pairs of crossing lines in black ink. The pattern grows from two ten-pointed quarter stars at the upper corners and a ten-pointed half star along the bottom edge, interlocking with polygons and double bipeds.
Dimensions: 24.5 × 35.2 cm.
Condition: Pasted near the right edge where the design has slipped slightly.
Technique: Uninked radial grid lines of concentric quarter circles and semicircles with four and nine radii, respectively, at the upper corners and along the bottom edge generate the stars. Alternating radii emanating from the two upper corners form a V shape and extend up to the uninked vertical axis of symmetry that bisects the pattern into bilaterally symmetrical halves. An uninked horizontal line passing from the center of the composition coincides with some sides of polygons aligned along it.

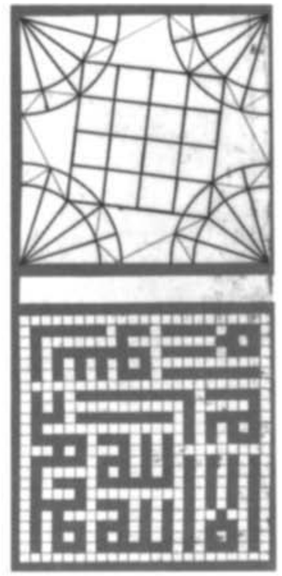


65.
Subject: Square kufic calligraphic panel on a squared grid.
Dimensions: 24.5 × 24.5 cm. Each square of the grid measures 0.4 × 0.4 cm.
Condition: Fine. Mistake has been corrected in one place by pasting a piece of squared paper on top of the error.
Technique: Both the squared grid and the kufic inscription are rendered in black ink. The inked squares of the grid were first marked as dots by the point of a compass or joined with a black-ink line before being filled with ink.
Inscription: Undeciphered.



66.
Subject: Quarter repeat unit of a star-and-polygon pattern with no dotted or solid grid lines. The symmetrical pattern has ten-pointed quarter stars at each corner that interlock with pentagons and other polygons; the center of the composition is occupied by a four-pointed star.
Dimensions: 24.5 × 24.3 cm.
Condition: Pasted near the middle where the design has slipped slightly.
Technique: Uninked radial grid lines of concentric quarter circles with four radii appear at each corner. Two uninked diagonal axes of symmetry cross at the center of the four-pointed star (these axis lines are not, however, extended up to the four corners of the repeat unit). In addition, two uninked horizontal and vertical lines intersect at the center of the repeat unit, passing from some important points.





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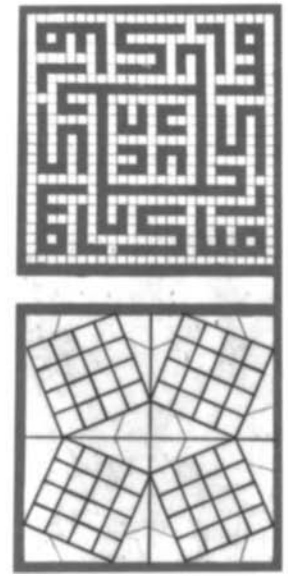
b



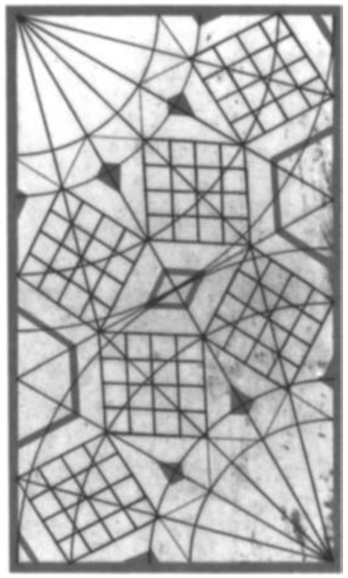
a

b

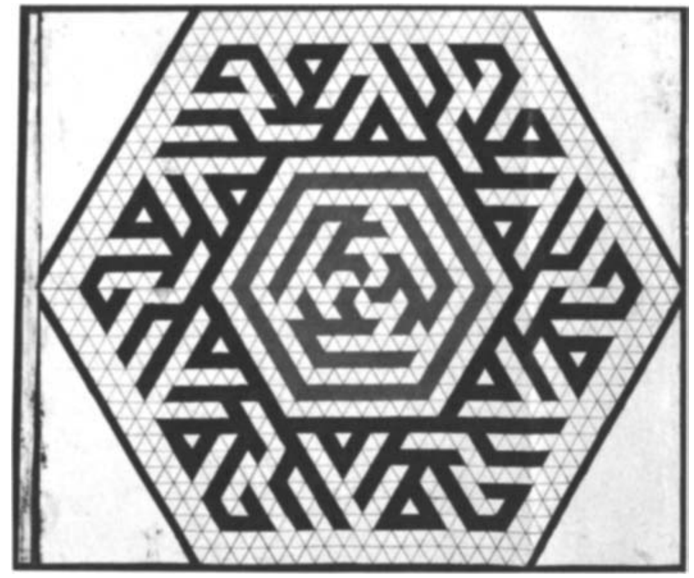
67.
Subject: Quarter repeat unit of a star-and-polygon pattern with rotating squares containing swastikas. The pattern grows from two eight-pointed quarter stars at the upper corners and an eight-pointed half star along the bottom edge, which interlock with various polygons.
Dimensions: 24.5 × 20.5 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles and semicircles with three and seven radii, respectively, generate the stars at the upper corners and along the bottom edge. Two of the radii emanating from the upper corners extend up to the midpoint of the bottom edge of the repeat unit, forming a V-shaped axis of symmetry along which design elements are aligned. An uninked horizontal line passes through the center of the composition, determining the midpoints of the swastikas. It is accompanied by an uninked vertical axis of symmetry that bisects the pattern into bilaterally symmetrical halves. The two swastikas are generated by two rotated squares subdivided into sixteen smaller squares, but these construction lines are not indicated on the pattern.

68.
Subject: (a) Quarter repeat unit of a star-and-polygon pattern with a rotated central swastika. The drawing in black ink grows from ten-pointed quarter stars at each corner.
Dimensions: Contained together with cat. no. 68b in a rectangular frame, 24.5 × 11 cm. The repeat unit measures 11 × 11 cm.
Condition: Pasted along the right edge; intact. A line at the upper left corner (which would have made the composition symmetrical) is missing.
Technique: Uninked radial grid lines of concentric quarter circles with four radii generate the stars at each corner. These are accompanied by an uninked rotated central square subdivided into a checkered grid of sixteen uninked small squares that guide the outlines of the swastika.
Subject: (b) Square kufic calligraphic panel on a squared grid.
Dimensions: 11 × 11 cm. The squares of the inked grid measure 0.4 × 0.4 cm.
Condition: Pasted along the right edge; intact.
Technique: The inscription in red ink is superimposed on the squared grid drawn in black ink. The redundant black-ink lines joining some of the squares are corrected with white paint.
Inscription: "Lā ilāha illā' llāh Muḥammad Rasūl Allāh" (There is no God but God and Muhammad is his Prophet), the Muslim profession of faith.

69.
Subject: (a) Square kufic calligraphic panel on a squared grid.
Dimensions: Contained together with cat. no. 69b in a rectangular frame, 24.5 × 11 cm. The repeat unit measures 11 × 11 cm. The squares of the inked grid measure 0.4 × 0.4 cm.
Condition: Fine.
Technique: The red inscriptions are superimposed on the squared grid drawn in black ink.
Inscriptions: "Mubārak bād" (May he [or it] be blessed!, or, Good fortune attend you!), rotated four times.
Subject: (b) Repeat unit for a polygonal pattern with four rotated swastikas; the center is occupied by an octagon.
Dimensions: 11 × 11 cm.
Condition: Fine. Two lines that would have created a pentagon along the left edge of the repeat unit are missing.
Technique: The uninked grid lines consist of two vertical and horizontal axes of symmetry intersecting at the center of the repeat unit. Each of the quadrants defined by these axes features an uninked rotated square subdivided into sixteen smaller squares that guide the outlines of the swastikas drawn in black ink. The pattern is also symmetrical along its unindicated diagonal axes passing from the center of the composition.

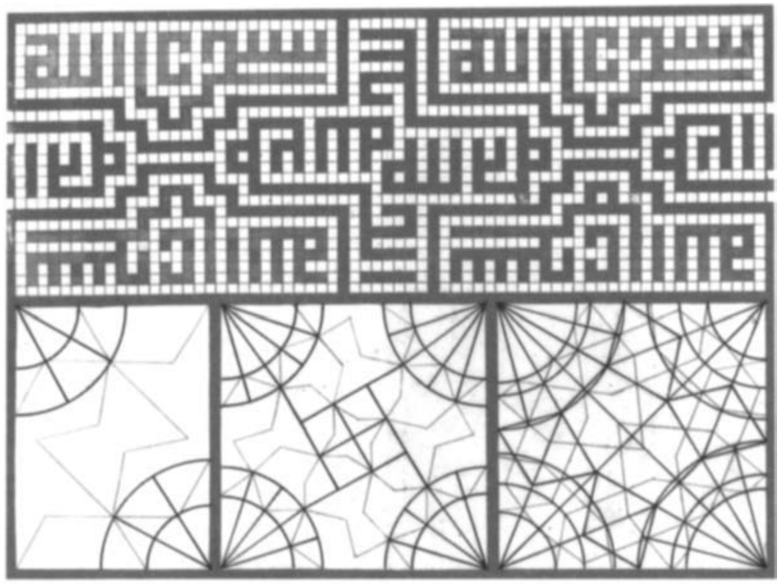


70.
Subject: Quarter repeat unit of a pattern with swastika motifs. It grows from two twelve-pointed quarter stars at the upper left and lower right corners, interlocking with rhomboids, half hexagons, and rhombuses containing swastikas.
Dimensions: 24.5 × 14 cm.
Condition: Fine. The orange metallic paint has tarnished into silvery gray.
Technique: Uninked radial grid lines of concentric quarter circles, each with five radii, generate the stars at the upper left and lower right corners. Other uninked construction lines consist of six rhombuses, each subdivided into a grid of sixteen small rhombuses that guide the outlines of the swastikas drawn over them in black ink. The repeat unit also has two uninked axes of symmetry that intersect at the center; one of them is the diagonal that joins the two starred corners. The other is an oblique axis that determines the centers of the half hexagons along the lateral edges, bisecting the central rhombus between them. The black-ink pattern is highlighted with orange, possibly to indicate differently colored tiles or inset plaques.



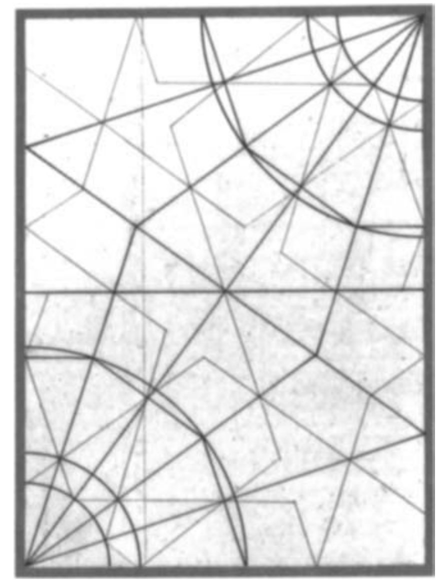
71.
Subject: Hexagonal panel with kufic inscriptions drawn on a triangulated grid.
Dimensions: Contained in a rectangular frame, 24.5 × 28.5 cm. Each side of the hexagon measures 14.2 cm. The equilateral triangles of the grid measure 0.8 cm on each side.
Condition: Pasted along the left edge; intact.
Technique: The empty triangles at the four corners of the repeat unit crisscross with uninked arcs used in generating the outer hexagon. Several uninked lines guide the composition inside the hexagon. The triangulated grid and the outer hexagonal inscription band are rendered in black ink; the inner hexagon and its inscriptions are in red ink. This color coding probably refers to the differently colored tiles meant to be used in the rotationally symmetrical panel.
Inscriptions: Around the hexagonal outer band "Muḥammad" is repeated six times; inside the central hexagon "ʿAlī" is rotated three times.

a

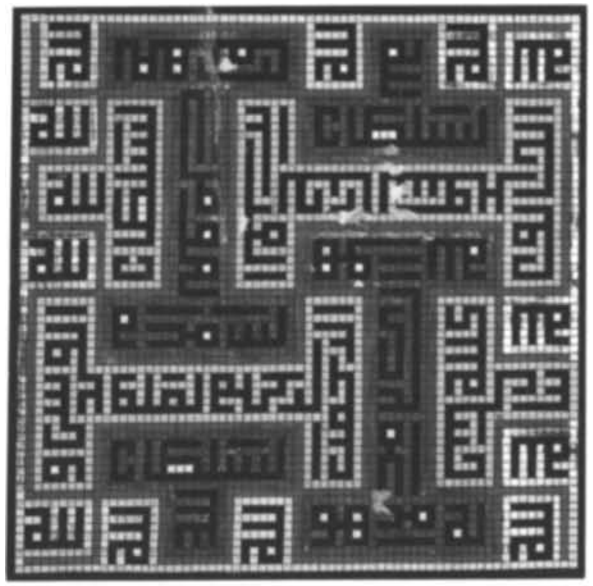


b c d

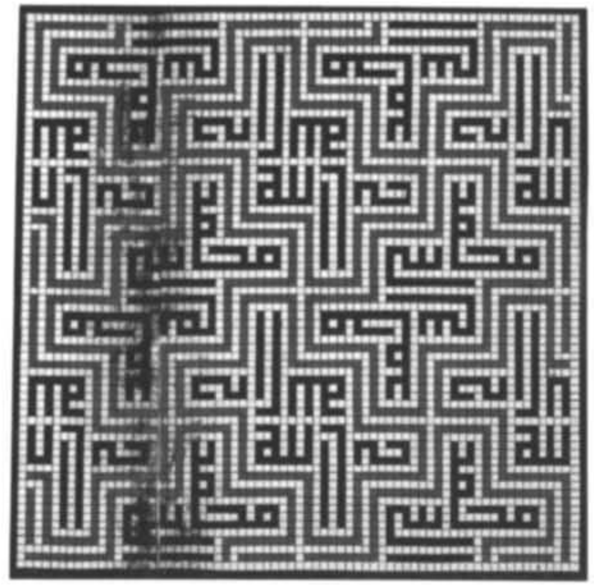
72.
Subject: (a) Linear repeat unit of a composite square kufic calligraphic panel with a central cross-shaped pattern, drawn on a squared grid.
Dimensions: Contained together with cat. no. 72b–d in a rectangular frame, 24.5 × 33.2 cm. The repeat unit measures 12.2 × 33.2 cm. The squares of the grid measure 0.5 × 0.5 cm.
Condition: Pasted along the left edge; intact. The orange metallic paint has tarnished into silvery gray.
Technique: The squared grid in black ink is superimposed with black-ink kufic letters contained in the central cross and the two partial crosses attached to it. The lateral T-shaped frames feature orange kufic lettering. The color coding refers to the differently colored glazed bricks meant to be used in *bannā'ī* masonry for this design, extendable in two directions along a linear axis.
Inscriptions: The central cross in black ink contains "Al-ḥamd li'llāh" (Praise be to God!) repeated twice; the two arms of the incomplete black-ink crosses attached to it feature fragments of the same phrase that were meant to be completed by multiplying the repeat unit. The lateral T-shaped frames each contain "Subḥān Allāh" (Praise be to God!) colored in orange paint. There are errors in the spelling of "Allah" and "Subḥān" at the upper and lower T-shaped frames on the right side.
Subject: (b) Quarter repeat unit of a star-and-polygon pattern with no solid or dotted grid lines. It is composed of two six-pointed quarter stars at the upper left and lower right corners, interlocking with various polygons drawn in black ink.
Dimensions: 11.8 × 8.7 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles with two radii generate the stars at the upper left and lower right corners. No other uninked construction lines are indicated, even though the repeat unit is symmetrical with respect to its diagonal axis connecting the starred corners and an oblique axis passing from the center that bisects the double trapezoids in the shape of a bow tie.
Subject: (c) Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines define a central rotated square with four extended sides that intersect with the points of the ten-pointed quarter stars in each corner. The pattern in black ink that grows from these stars is composed of interlocking polygons; its center is occupied by a four-pointed star fitted into the red-dotted rotated square.
Dimensions: 11.8 × 11.8 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with four radii appear at each corner. The incised outlines of the rotated central square, subdivided into four uninked small squares, and its four extended sides are gone over in red-dotted lines that probably would have been eliminated from the final design.
Subject: (d) Quarter repeat unit of a star-and-polygon pattern in two layers. The red-dotted grid lines define stars and polygons in contact (quarter dodecagons, eight-pointed quarter stars, rhombuses, and elongated hexagons) whose sides are bisected by the crossing lines of the main pattern drawn in black ink. The pattern grows from two twelve-pointed quarter stars at the upper left and lower right corners, interlocking with various polygons and overlapping double bipeds at the center. This is a variant of cat. no. 53, which also has two overlapping central bipeds along its diagonal axis that connects the corner stars.
Dimensions: 11.8 × 11.8 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with three and five radii, respectively, appear at the four corners. The repeat unit has two uninked axes of symmetry, the diagonals that connect opposite corners and intersect at the center of the composition.



73.
Subject: Quarter repeat unit of a star-and-polygon pattern without dotted or solid grid lines. It grows from two ten-pointed quarter stars at the upper right and lower left corners, interlocking with polygons and double bipeds.
Dimensions: 24.5 × 17.8 cm.
Condition: Pasted near the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles, each with four radii, appear at the starred diagonal corners. The repeat unit has two uninked axes of symmetry that intersect at the center of the composition. One of them is the diagonal that joins the two starred corners; the other is an oblique axis that passes through the intersection point of the two central double bipeds facing each other. These construction lines are accompanied by an uninked horizontal axis of symmetry that divides the composition into two symmetrical halves.



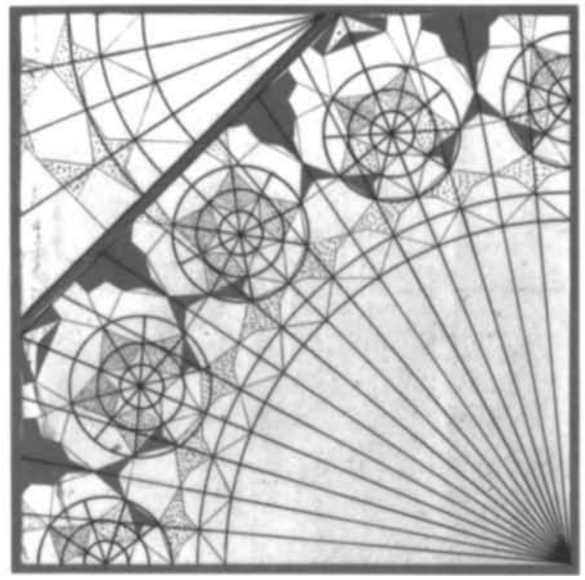
74.
Subject: Composite square kufic calligraphic panel drawn on a squared grid with interlocking I- and T-shaped fields, colored green and yellow. Together with the light pink areas around the edges of the repeat unit, these colors define individual fields for differently colored glazed bricks. The orange lines framing these color-coded fields form swastikas at the four corners, the midpoints of the four sides, and at the center of the repeat unit.
Dimensions: 24.5 × 24.5 cm. The squares of the inked grid measure 0.3 × 0.3 cm.
Condition: The metallic orange paint has tarnished into silvery gray, and the faded light pink color is uneven. Some parts of the design are torn. Some spelling errors (e.g., "al-mutakabbir").
Technique: The squared grid in black ink is filled with various colors, including green, orange, light pink, and yellow. The kufic lettering is black.
Inscriptions: The yellow I-shaped areas are filled with the following Beautiful Names of God (i.e., *al-asmā' al-ḥusnā'*): "al-raḥmān" (the Beneficient), "al-raḥīm" (the Merciful), "al-malik" (the Sovereign Lord), "al-quddūs" (the Holy One), "al-ʿazīz" (the Majestic), "al-jabbār" (the Compeller), "al-mutakabbir" (the Superb), and "al-khāliq" (the Creator). The green I-shaped areas quote parts of the Koranic verse (59:23) in which some of the ninety-nine Beautiful Names of God are mentioned, but the ones already cited in the yellow I-shaped areas (i.e., "al-malik," "al-quddūs," "al-ʿazīz," "al-jabbār," and "al-mutakabbir") are not repeated here. The green and yellow T-shaped areas distributed along the repeat unit's frame read "li'llāh" (God's) and "al-sulṭān" (the Sultan). The small light pink rectangles also lined up along the repeat unit's frame contain only "li'llāh" (God's).



75.
Subject: Composite square kufic calligraphic panel drawn on a squared grid with black letters separated by parallel red lines (each of them one square wide) forming swastikas at the center of each of the four quadrants and at the center of the repeat unit.
Dimensions: 24.5 × 24.5 (top), 24.7 cm (bottom). The squares of the inked grid measure 0.3 × 0.3 cm.
Condition: Pasted near the left edge where the paint is smudged.
Technique: The squared grid in black ink is filled with black lettering and parallel red lines that frame the letters.
Inscriptions: "Muḥammad Nabiyyu" (Muhammad is the Prophet [of God]) and "Allāh Aḥad" (God is unique), repeated twice in each frame and once in the half frames along the sides of the repeat unit.

76.
Subject: Square kufic calligraphic roundel drawn on a squared grid.
Dimensions: Contained in a square frame, 24.5 × 24.5 cm. The squares of the inked grid measure 0.7 × 0.7 cm.
Condition: Fine.
Technique: Both the squared grid and the calligraphic roundel are rendered in black ink. Uninked parallel circles and horizontal and vertical axes of symmetry intersecting at the center guide the composition.
Inscriptions: "Muḥammad, ʿAlī," rotated four times, once in each quadrant.

a



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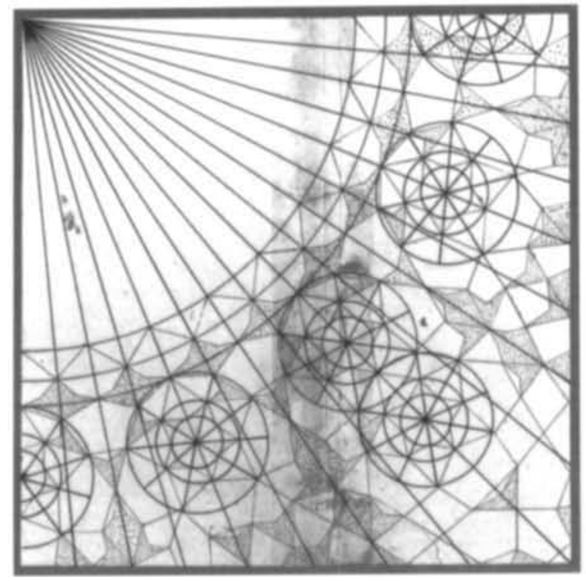
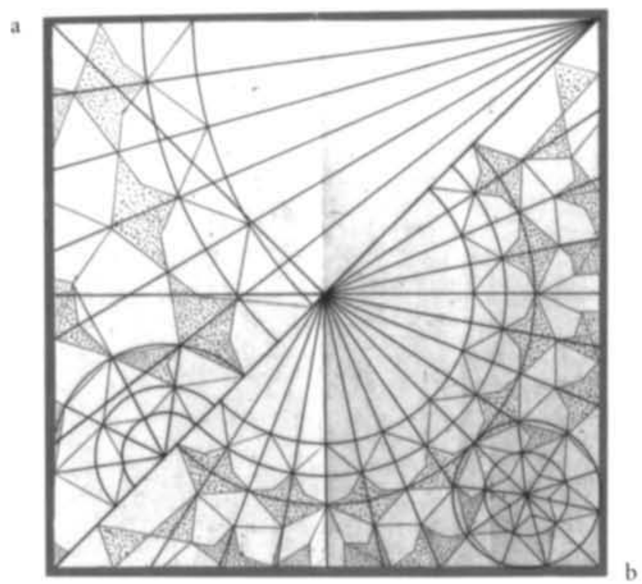
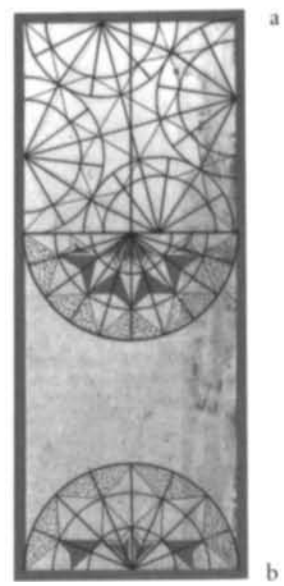


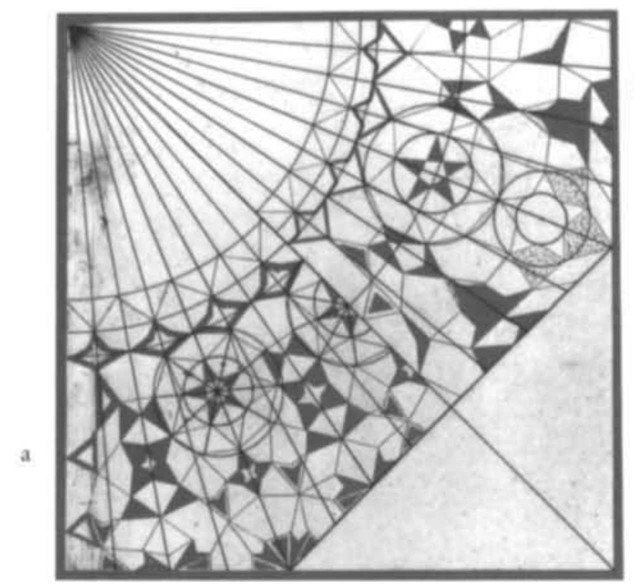
77.
Subject: Composite square kufic calligraphic panel drawn on a squared grid, with orange letters contained in square compartments occupying each corner and at the center of the composition. The remaining letters in black ink are framed by red lines that form swastikas at the center of each side of the repeat unit.
Dimensions: 24.5 × 24.5 cm. The squares of the inked grid measure 0.3 × 0.3 cm.
Condition: Pasted near the left edge; intact. A red line is missing along the bottom edge where "Muḥammad" is written. Some of the orange metallic paint has tarnished into silvery gray.
Technique: The squared grid in black ink is filled with orange and black lettering and framing red lines.
Inscriptions: The four longest black-lettered frames read "Lā ilāha illā' llāh Muḥammad," and each of the orange-lettered squares is filled with "Rasūl Allāh." Together they form the Muslim profession of faith, "Lā ilāha illā' llāh Muḥammad Rasūl Allāh" (There is no God but God and Muhammad is his Prophet). The four shorter L-shaped frames contain "Muḥammad," and the small rectangular ones along the repeat unit's edges read "li'llāh" (God's).

78.
Subject: (a) The corner triangle has the repeat unit of a kite-shaped rhomboidal muqarnas fragment probably meant to be used in the transitional zone of the octagonal vault depicted in cat. no. 78b. If used independently, it could be multiplied eight times to form an octagonal vault. Its fan-shaped radial muqarnas units are composed of simple polygons and arrow-shaped double bipeds with no stars.
Dimensions: Contained in a square frame, 24.6 × 24.6 cm. The base of the triangle measures 19.9 cm; its two equal sides are 13.5 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric arcs with three radii (full vault would have thirty-two-fold radial symmetry). The black-ink drawing is only highlighted with stippling in black; no color coding is used because of the relative simplicity of the pattern.
Subject: (b) Fan-shaped radial muqarnas quarter vault with the squinch corner cut off; multiplying the repeat unit four times would create an octagonal vault. It starts with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars.
Dimensions: Same as cat. no. 78a.
Condition: Same as cat. no. 78a. A color-coded biped, which should have been adjacent to the central star, is missing from what would otherwise have been a symmetrical composition.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (full vault would have sixty-four-fold radial symmetry) emanate from the lower right corner; these are accompanied by smaller subsidiary systems of concentric circles. The drawing in black ink has stippling and color coding in black and red ink to differentiate spatial levels and to highlight the filler units surrounding the star clusters. Two different densities of black stippling are used to indicate that the five-pointed stars bend toward three different planes.

79.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars merging with the five-pointed star in the squinch corner, which is filled by polygonal shapes.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted along the middle where the design has slipped slightly. The symmetry of the repeat unit is destroyed by errors in stippling in the right half, where two stippled bipeds are missing. At the upper right edge the points of a half star have been stippled by mistake. Hole near the center.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (full vault would have sixty-four-fold radial symmetry) and smaller subsidiary systems of circles. The black-ink drawing has only black stippling used to highlight the double bipeds and the filler units demarcating the tiers around the star clusters. As in cat. no. 80 the stars have not been stippled or color coded to differentiate spatial levels.



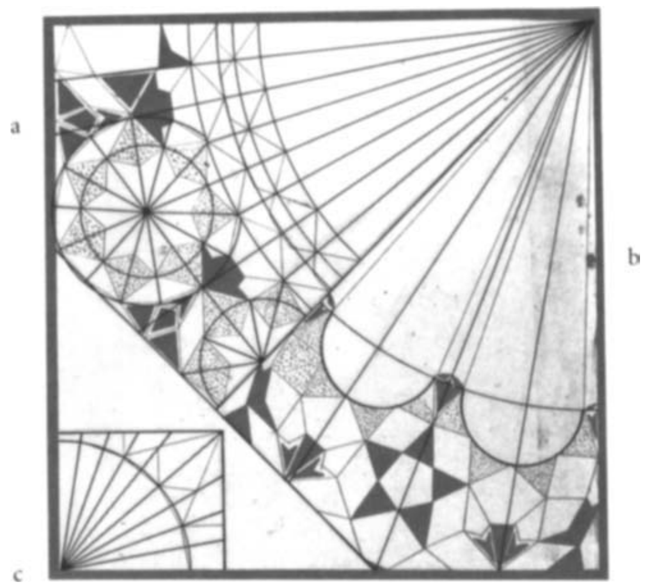




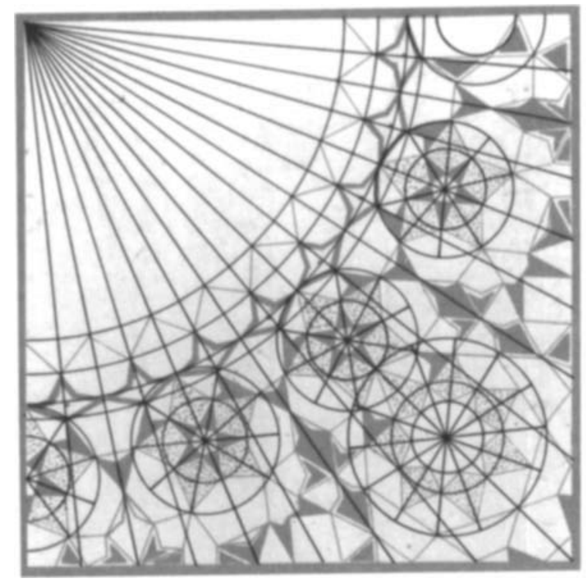
80.
Subject: (a) Fan-shaped radial muqarnas pattern contained in a triangle constituting the one-eighth repeat unit of a square full vault, or the one-half fragment of a square pattern for the transitional zone of a vault. Rows of hexagons and arrow-shaped double bipeds are not accompanied by intermediary stars; one corner has a five-pointed half star.
Dimensions: Contained in a square, 24.5 × 24.5 cm. The diagonal line constituting the base of each triangular repeat unit is 34.6 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric arcs with five radii (full vault would have forty-eight-fold radial symmetry), accompanied by concentric semi-circles generating the half star in the lower corner. The black-ink drawing has only black stippling because of the relative simplicity of its muqarnas design, which lacks multiple stars. Stippling is used only to highlight the single and double bipeds; the corner star is left unstippled as in cat. nos. 79 and 80b.
Subject: (b) Fan-shaped radial muqarnas contained in a triangle, sharing the same characteristics as cat. no. 80a. It starts with rows of hexagons and double bipeds and its corner is occupied by a five-pointed star framed by an irregular octagon. It could be used to fill a triangular squinch corner or a triangular frame along the baseline of a dome, or doubled to form a square full vault. These two drawings seem to present two possible vaulting options using similar design elements.
Dimensions: Same as cat. no. 80a.
Condition: Fine.
Technique: Uninked radial grid lines of concentric semi-circles with fifteen radii (full vault would have thirty-two-fold radial symmetry), complemented by smaller concentric circles around the corner star; graphic conventions same as cat. no. 80a. Two uninked diagonals and a horizontal line intersect at the center of the square repeat unit containing cat. no. 80.

81.
Subject: (a) Quarter repeat unit of a star-and-polygon pattern in black ink without dotted or solid grid lines. It is composed of four seven-pointed half stars, one along each edge, interlocking with pentagons adjacent to a central rotated square.
Dimensions: Contained in a rectangular frame, 24.5 × 9.3 cm. The square repeat unit measures 9.3 × 9.3 cm.
Condition: Fine. Hole at the top.
Technique: Uninked radial grid lines of concentric semi-circles, each with six radii, generate the half stars. Their centers are determined by two uninked oblique axes of symmetry intersecting at the middle of the composition. An uninked vertical line passing from the center of the repeat unit coincides with the central axis of the accompanying pattern cat. no. 81b.
Subject: (b) Two variants of stellate muqarnas cornices for the organ-pipe ribs of ribbed domes.
Dimensions: Contained in a rectangular frame, 15 × 9.3 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric semi-circles (the one on top has nine radii and the bottom one has seven) generate the stellate muqarnas patterns drawn in black ink. Each example has been highlighted with stippling in black ink and color coding in black and red ink to differentiate spatial levels and to highlight biped-shaped filler units.

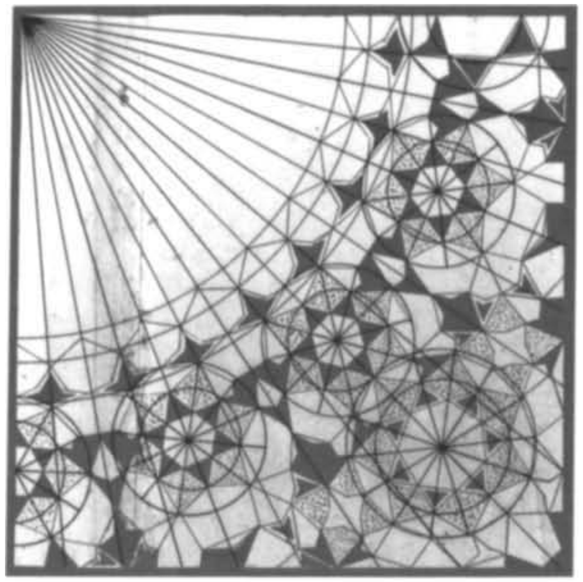
82.
Subject: (a, b) Two similar design options for a fan-shaped muqarnas vault, each with a central unbent five-pointed star on a single plane. Both rhomboidal patterns represent the one-eighth repeat unit of a muqarnas full vault starting with rows of hexagons and arrow-shaped double bipeds, followed by rows of stars. In cat. no. 82a a row of five-pointed stars contained in decagons is followed by another row of four-pointed stars framed by rotated squares that alternate with other four-pointed stars. In cat. no. 82b there are two central five-pointed stars, one of them unbent and the other one with two bent points. The use of asymmetrical polygonal units along the two long left sides of each rhomboidal repeat unit indicates that they probably were meant not for full vaults but for octagonal half vaults. Since both repeat units have half stars along their right edges, they would have been multiplied along those edges and were not intended for the kite-shaped transitional zones of vaults.
Dimensions: Contained in a frame, 24.5 × 24.3 cm. The short sides of the rhomboids measure 10 cm. The corner triangle has a base of 20.3 cm and two equal sides of 14.3 cm.
Condition: Pasted near the left edge where the design has slipped slightly.
Technique: An uninked diagonal divides the repeat unit into two halves. Each drawing has uninked radial grid lines of concentric arcs with seven radii (half vaults would have thirty-two-fold radial symmetry) and smaller subsidiary systems of circles. Cat. no. 82a is a black-ink drawing color coded with black and red ink; cat. no. 82b is a black-ink drawing highlighted with black stippling and color coding in black and red ink. In both drawings the unbent flat stars are colored red and black, perhaps to indicate mosaic tile insets used in conjunction with plaster. Only cat. no. 82b has a black-stippled corner star with two bent points.



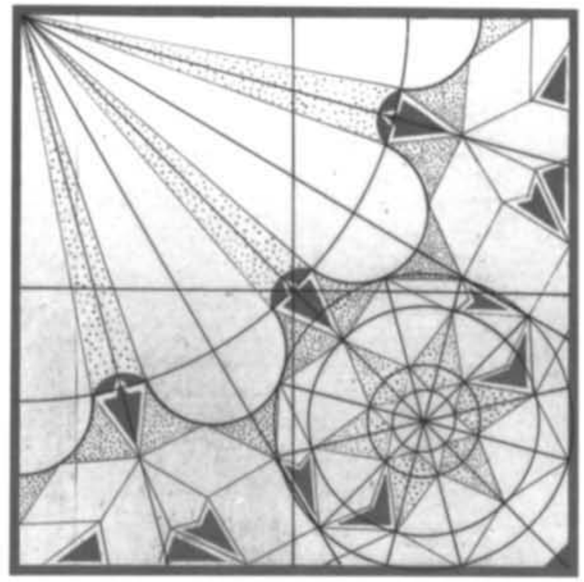
83.
Subject: (a) Fan-shaped radial muqarnas pattern representing the rhomboidal one-eighth repeat unit of an octagonal vault. The use of asymmetrical polygonal units along the upper left edge, however, suggests that the repeat unit was intended for an octagonal half vault. The half star along the right edge reveals that the pattern, which would have been repeated along that edge, was not meant for the kite-shaped transitional zones of vaults. It starts with rows of hexagons and arrow-shaped double bipeds, followed by a single row of six- and seven-pointed stars.
Dimensions: Contained together with cat. no. 83b–c in a square, 24.5 × 24.5 cm. The shorter sides of the rhomboids measure 10 cm. The corner triangle has a base of 20.2 cm and equal sides measuring 14 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric arcs with seven radii (half vault would have thirty-two-fold radial symmetry) accompanied by smaller subsidiary systems of circles. The black-ink drawing is highlighted with red and black stippling and color coding in red and black ink to differentiate spatial levels. Colors highlight the filler units surrounding the black-stippled stars whose bent points are indicated by red stippling.
Subject: (b) Shell-shaped radial muqarnas pattern representing the one-eighth rhomboidal repeat unit of an octagonal vault; it could also be used in the kite-shaped transitional zone of a vault. It has a single five-pointed star contained in a pentagon, flanked by simple polygonal units.
Dimensions: Same as cat. no. 83a.
Condition: Pasted along the right edge; intact. Although a rhombus along the left side has stippling (probably a mistake), the corresponding rhombus along the right side is unstippled.
Technique: Uninked radial grid consisting of an arc with three radii (full vault would have thirty-two-fold radial symmetry). The black-ink drawing has stippling in black and color coding in black and red ink to differentiate spatial levels and to highlight filler units. The five-pointed unbent red star is on a single plane.
Subject: (c) Arch-net quarter vault with an eighteen-sided polygon at the center; it was probably meant to be used as a semidome at the transitional zone of the vaults depicted in cat. no. 83a–b.
Dimensions: 6.2 × 7.4 cm.
Condition: Fine.
Technique: An uninked arc with eight radii generates the stellate pattern drawn in black ink.



84.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars, with the squinch corner occupied by a large seven-pointed star. The use of asymmetrical polygonal units at the upper right edge indicates that the repeat unit was not meant for a full vault but for a half vault.
Dimensions: 24.5 × 24.5 cm.
Condition: Fine. Filler unit at the left end of the bottom edge is uncolored, unlike its symmetrical counterpart along the upper right edge of the repeat unit.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (half vault would have thirty-two-fold radial symmetry) and smaller subsidiary systems of circles. Stippling and color coding in black and red ink are used to differentiate spatial levels and to highlight filler units surrounding the stars. The five-pointed stippled stars contain red-colored stars, perhaps meant to be executed as mosaic tile insets embedded in the plaster. All the stars stippled in red and black ink have one point bending toward a different plane.

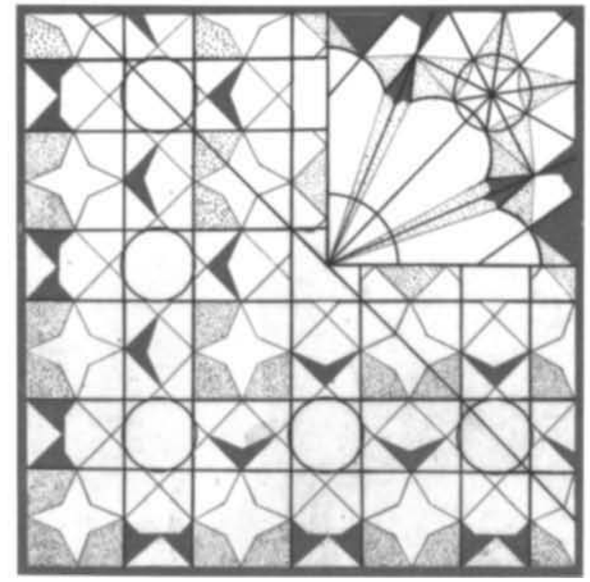


85.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of six-pointed stars, with the squinch corner filled by a large seven-pointed star flanked by small four-pointed stars. The use of asymmetrical polygonal units at the upper right edge indicates that the repeat unit was not meant for a full vault but for a half vault.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted near the left edge where the design has slipped slightly.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (half vault would have thirty-two-fold radial symmetry) and smaller subsidiary systems of circles. Graphic conventions same as cat. no. 84. Here the six-pointed stars that contain smaller six-pointed flat stars have two points bending toward a different plane. The large seven-pointed corner star also has a black-colored flat star polygon set into it.



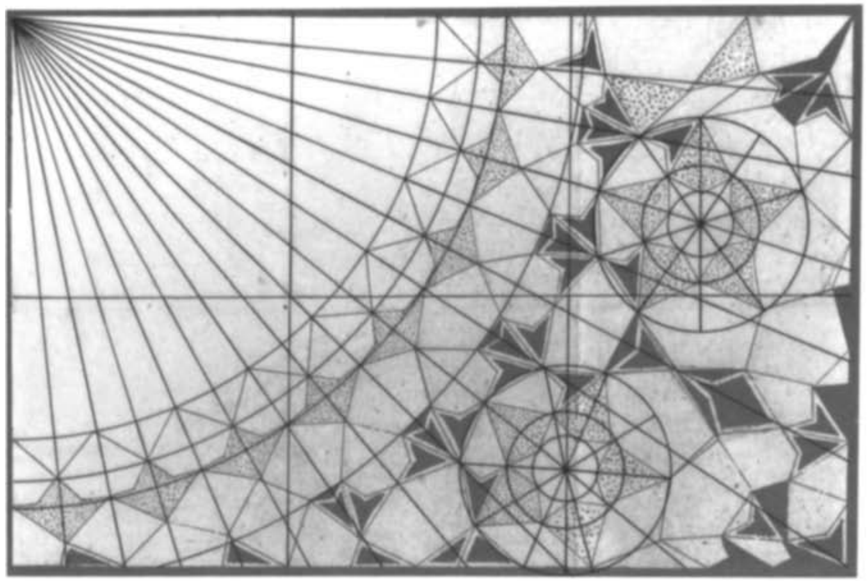
86.
Subject: Shell-shaped radial muqarnas quarter vault with simple polygonal units; the squinch corner is occupied by a six-pointed star.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted near the left edge; intact.
Technique: Uninked quarter circle with five radii (full vault would have twenty-four-fold radial symmetry) accompanied by smaller concentric circles in the squinch corner. Graphic conventions same as cat. no. 84. The three red-dotted points of the corner star fall on a different plane than the black-dotted ones. Uninked vertical and horizontal lines intersect at the center of the composition.

a

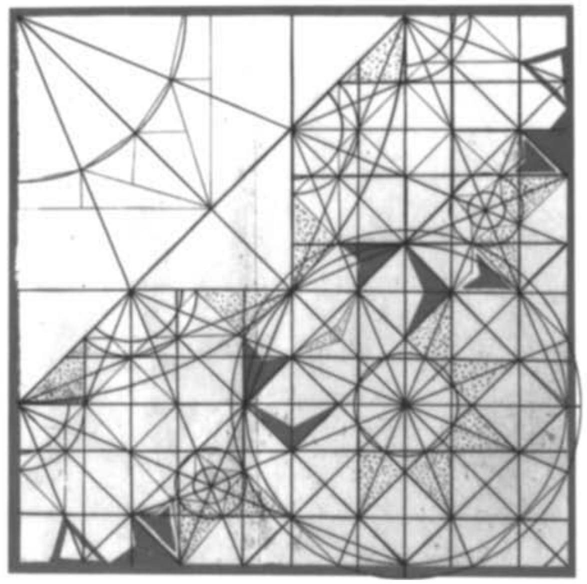


b

87.
Subject: (a) Repeat unit for a stellate muqarnas quarter vault based on a composite orthogonal and radial grid system with patterns limited to 45, 90, and 135 degrees. It is composed of four- and eight-pointed stars regulated by a grid of square and rectangular compartments. The accompanying drawing, cat. no. 87b, probably was meant to be used in conjunction with this one. When quadrupled this repeat unit would create a flat square muqarnas vault (probably rendered in wood or brick), with a square area at its center that may have been filled by multiplying cat. no. 87b four times. It is closely related to cat. no. 89.
Dimensions: 24.5 × 24.5 cm.
Condition: Fine.
Technique: The repeat unit is subdivided into square and rectangular compartments that are not, however, indicated as uninked vertical and horizontal lines. The rectilinear grid shown in the overlay is not present among the uninked construction lines, which only include circles containing the eight-pointed stars and an uninked oblique line touching the corner of cat. no. 87b. Stippling and color coding in black and red ink are used to differentiate spatial levels and to accentuate bipeds. Black stippling is used only in the triangular compartments that surround the frame of cat. no. 87b.
Subject: (b) Shell-shaped radial muqarnas quarter vault with its squinch corner occupied by a five-pointed star with one point missing. When quadrupled this pattern would form a square dome with an eight-fluted central shell; it was probably meant to fill the center of the vault depicted in cat. no. 87a. The drawings are proportionally related and share sixteen-fold radial symmetry.
Dimensions: 11 × 11 cm.
Condition: Fine. A line that should have divided the rhombus at the middle of the right edge into two triangles is missing.
Technique: Uninked arc with three radii (full vault would have sixteen-fold radial symmetry) and a smaller circle, subdivided by ten radii, at the corner. Graphic conventions same as cat. no. 87a.



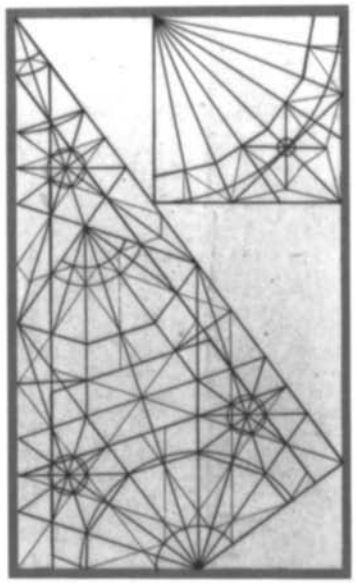
a

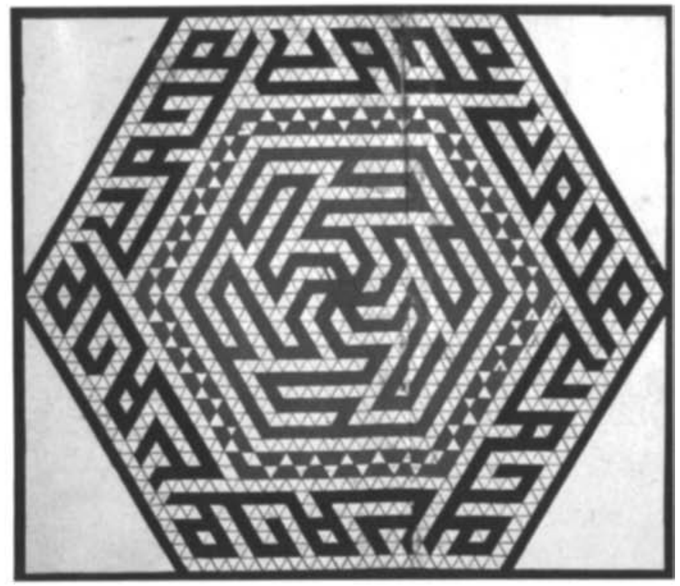


b

88.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars. The squinch corner has simple filler elements. The rectangular format has led to a relatively asymmetrical composition. The use of asymmetrical polygonal units along the upper right edge indicates that the repeat unit was meant not for a full vault but for a half vault.
Dimensions: 24.5 × 37 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (half vault would have thirty-two-fold radial symmetry) and smaller subsidiary systems of circles. Two uninked vertical lines, bisected by a horizontal one passing from the center of the composition, subdivide the rectangular repeat unit into six squares. Graphic conventions same as cat. no. 87.

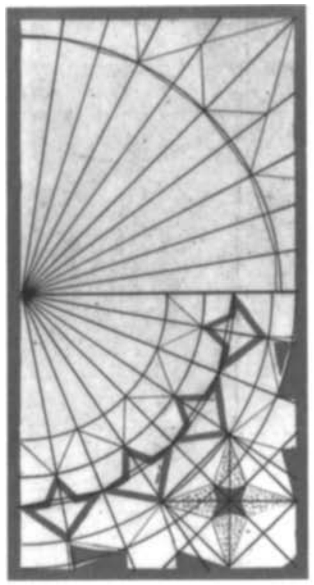
89.
Subject: (a) Arch-net quarter vault with a central sixteen-sided polygon.
Dimensions: Contained together with cat. no. 89b in a square frame, 24.5 × 24.5 cm. Repeat unit of arch net measures 8.6 × 8.6 cm. The larger square around it is 12.2 × 12.2 cm. The corner triangle has a base of 24.5 cm and two equal sides of 17.3 cm.
Condition: Pasted near the middle of the square frame containing cat. no. 89; intact.
Technique: An uninked quarter circle with three radii (full vault would have sixteen-fold radial symmetry) generates the stellate pattern drawn in black ink. The three uninked radii are extended through the accompanying drawing, cat. no. 89b, where they pass from the centers of stars.
Subject: (b) Stellate muqarnas quarter vault based on a composite orthogonal and radial grid system, composed of four- and eight-pointed stars interlocking with squares and rhombuses limited to 45, 90, and 135 degrees. The four-pointed stars are contained in octagons just like the eight-pointed corner star. When quadrupled, a square vault with a central star octagon would be formed, with each corner filled by an eight-pointed star. Cat. no. 89a probably was meant to be used at the center of the vault depicted in cat. no. 89b or in conjunction with it.
Dimensions: Contained in a square, 24.5 × 24.5 cm.
Condition: Same as cat. no. 89a. A color-coded biped, which should have divided one of the rhombuses adjacent to the four-pointed star along the bottom edge, is missing.
Technique: Uninked radial grid lines of concentric circles and arcs with eight and sixteen radii, respectively, generate each of the four- and eight-pointed stars. These construction lines are accompanied by an uninked orthogonal grid of squares and rectangles. Large uninked circles containing a rotated square occupy the lower right corner. Several uninked diagonal lines cross the orthogonal grid. The three radii of cat. no. 89a pass through the centers of the stars. The complementary drawings, cat. no. 89a and cat. no. 89b, are proportionally related; they share sixteen-fold radial symmetry. Stippling and color coding in red and black ink are used to differentiate spatial levels and to mark filler units in the shape of bipeds and triangles. This pattern for a flat muqarnas vault (probably rendered in brick or wood) is closely related to cat. no. 87.





90.
Subject: (a) Kite-shaped rhomboidal vault section constituting the one-tenth repeat unit of a decagonal dome; it could also be used alone in the kite-shaped transitional zones of vaults. It is decorated with two-dimensional star-and-polygon patterns accompanied by red-dotted grid lines. The red dots define polygons in contact (triangles, pentagons, trapezoids, elongated hexagons, and decagon fragments) whose sides are bisected by pairs of crossing lines in black ink. The main pattern is composed of five- and ten-pointed stars interlocking with polygons and star fragments; a ten-pointed star occupies the apex of the dome.
Dimensions: Contained together with cat. no. 90b in a rectangular frame, 24.5 × 14.4 cm. The short sides of the rhomboid measure 8 cm.
Condition: Fine.
Technique: Uninked arcs and circles subdivided by equidistant radii generate each of the stars (full vault would have twenty-fold radial symmetry). An uninked central radius divides the repeat unit into two bilaterally symmetrical halves. Some uninked parallel lines guide the composition in black ink.
Subject: (b) Arch-net quarter vault with a central sixteen-sided polygon. It probably was doubled and used either in the transitional zone of the decagonal vault depicted in cat. no. 90a or in conjunction with the latter.
Dimensions: 8.3 × 8.3 cm.
Condition: Fine.
Technique: An uninked quarter circle with seven radii (full vault would have thirty-two-fold radial symmetry) generates the stellate pattern in black ink. Uninked lines intersect at the center of the four-pointed corner star.

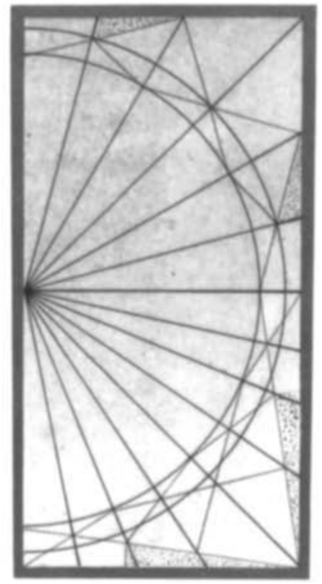
91.
Subject: Hexagonal calligraphic panel with kufic letters superimposed on a triangulated grid. The center of the composition is marked by a six-pointed star.
Dimensions: Contained in a rectangle, 24.5 × 28 cm. Each side of the hexagon measures 14 cm. The sides of the equilateral triangles of the grid measure 0.6 cm.
Condition: Pasted near the middle where the design has slipped slightly.
Technique: The triangulated grid lines drawn in black ink are superimposed with an outer hexagonal band of kufic inscriptions in black ink. In the middle is a rotating hexagonal inscription surrounded by a red hexagonal frame with decorative white triangles and rhombuses. Several uninked parallel oblique lines and horizontal and vertical axis lines intersecting at the center guide the composition.
Inscriptions: "Muḥammad" in black ink is repeated six times along the outer band, and at the center "ᶜAlī" in red ink is rotated six times.



a

b

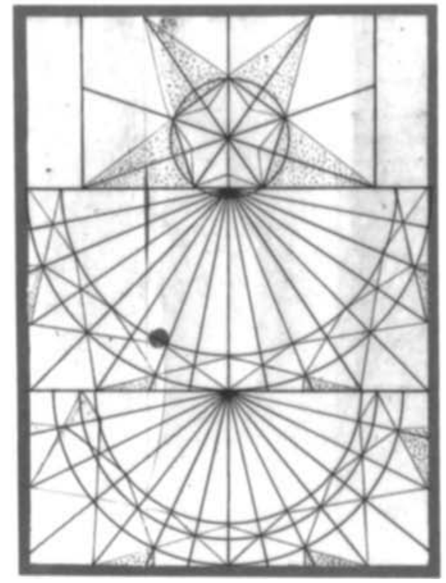
92.
Subject: (a) Stellate arch-net quarter vault with a central twenty-sided polygon. It provides an alternative option for vaulting with respect to cat. no. 92b.
Dimensions: Contained together with 92b in a rectangular frame, 24.4 × 12.2 cm. The square repeat unit measures 12.2 × 12.2 cm.
Condition: Fine.
Technique: An uninked quarter circle with nine radii (full vault would have forty-fold radial symmetry) generates the stellate pattern in black ink.
Subject: (b) Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds with no intermediary rows of stars; the squinch corner has a four-pointed star.
Dimensions: 12.2 × 12.2 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry). The corner star is contained in an uninked square bisected by one of the radii and marked by diagonal and horizontal lines intersecting at its center. Stippling in red ink and color coding in red and black ink are used to differentiate spatial levels and to highlight triangular filler units. The flat corner star has no bent points.



a

b

93.
Subject: (a) Stellate arch-net quarter vault with a central twelve-pointed star. It provides an alternative vaulting option with respect to cat. no. 93b.
Dimensions: Contained together with cat. no. 93b in a rectangular frame, 24.4 × 12.2 cm. The square repeat unit measures 12.2 × 12.2 cm.
Condition: Fine.
Technique: Uninked quarter circles with five radii (full vault would have twenty-four-fold radial symmetry) generate the stellate pattern in black ink. Stippling with red ink is used at the edges to differentiate spatial levels.
Subject: (b) Stellate arch-net quarter vault with a central sixteen-pointed star.
Dimensions: 12.2 × 12.2 cm.
Condition: Fine.
Technique: Uninked quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry) generate the stellate pattern in black ink, highlighted by red stippling along the edges to differentiate spatial levels.

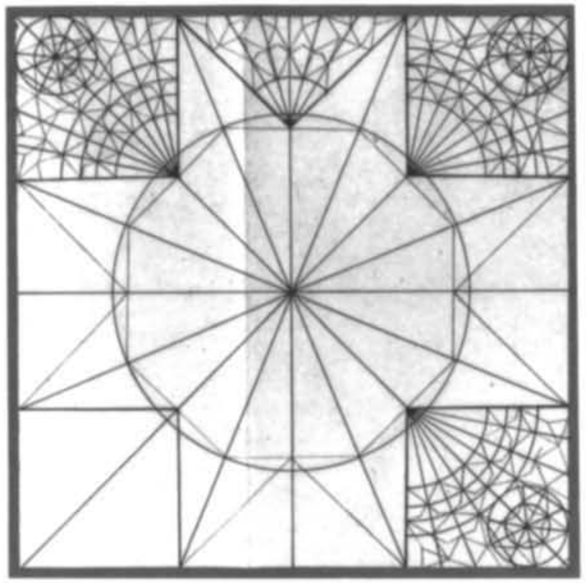


a

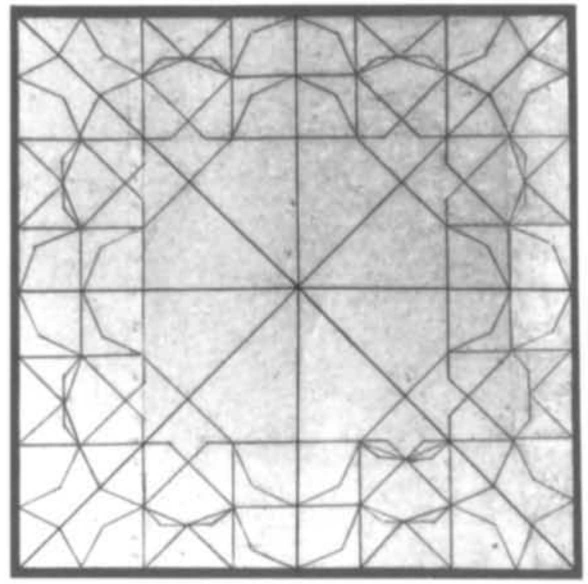
b

c

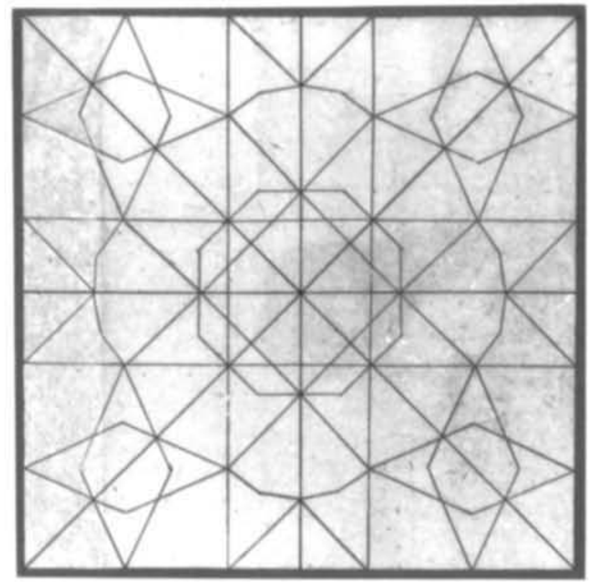
94.
Subject: (a) Detail of a stellate arch-net vault with an elongated four-pointed star. It contains a smaller five-pointed star framed by a pentagon. Cat. no. 94b–c provides alternative options for arch-net vault patterns.
Dimensions: Contained together with cat. no. 94b–c in a rectangular frame, 24.4 × 17.8 cm. The repeat unit measures 7.6 × 13.2 cm.
Condition: Pasted near the left edge; intact.
Technique: An uninked circle inscribed with a pentagon drawn in red ink is subdivided by ten radii. The black-ink drawing is stippled with red ink to differentiate spatial levels.
Subject: (b) Stellate arch-net half vault with a central sixteen-pointed star.
Dimensions: 9 × 17.8 cm.
Condition: Same as cat. no. 94a. Spot of black ink.
Technique: Uninked radial grid lines of concentric semicircles with fifteen radii (full vault would have thirty-two-fold radial symmetry) generate the stellate drawing in black ink. Stippling in red ink is used at the edges to differentiate spatial levels.
Subject: (c) Stellate arch-net half vault with a central fourteen-pointed star.
Dimensions: 7.8 × 17.8 cm.
Condition: Same as cat. no. 94a. Triangle along the left edge was left unstippled unlike its symmetrical counterpart along the right edge.
Technique: Uninked radial grid lines of concentric semicircles with thirteen radii (full vault would have twenty-eight-fold radial symmetry) generate the black-ink drawing whose graphic conventions are the same as cat. no. 94b.



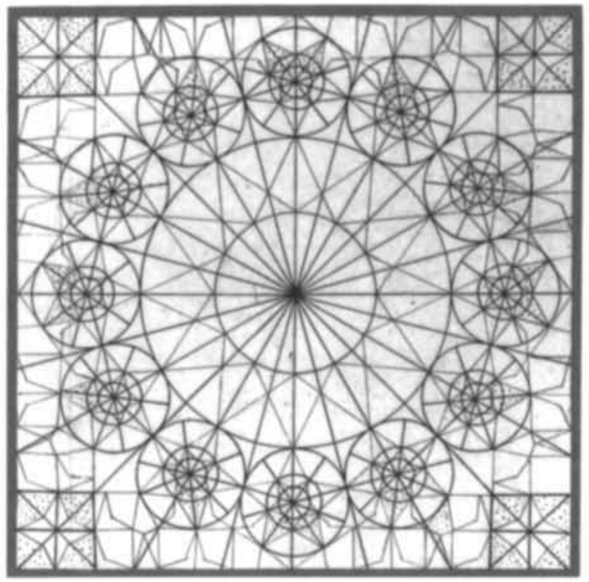
95.
Subject: Stellate muqarnas full vault composed of simple polygonal compartments. A central octagon that grows into an eight-pointed star defines square and triangular compartments along the edges meant to be filled with minute fan-shaped muqarnas units, only some of which are indicated. Drawings in this part of the scroll (cat. nos. 95–105) provide simpler black-ink outlines for patterns schematically representing the main compartmental divisions of vaults. Some compartments have been fragmented by broken lines to indicate that they would have been composed of three-dimensional elements.
Dimensions: 24.4 × 24.4 cm.
Condition: Fine.
Technique: An uninked circle inscribed with the central inked octagon has sixteen radii that extend to the outer frame of the repeat unit. Each of the square and triangular compartments along the edges of the pattern that are filled with muqarnas units features uninked radial grid lines of concentric quarter circles and arcs accompanied by smaller subsidiary circles, all of them subdivided by equidistant radii. The drawing is rendered only in black ink.



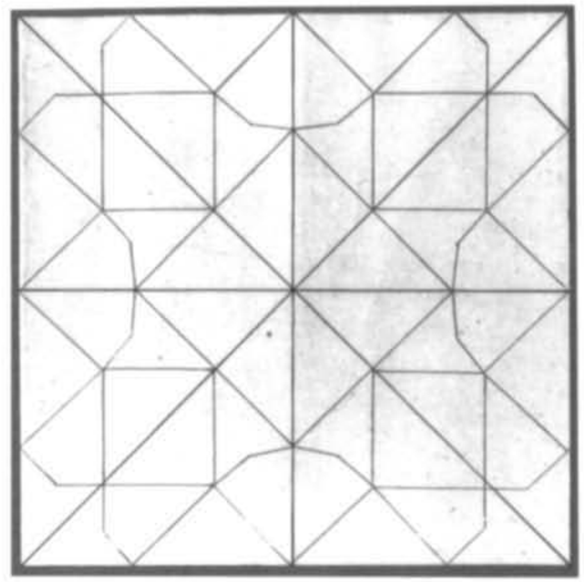
96.
Subject: Stellate muqarnas vault for a full square bay based on a composite orthogonal and radial grid system, with a large central octagon and four-pointed corner stars contained in squares. This is a nearly exact replica of cat. nos. 3 and 27 (constituting two halves of a single drawing) from which the stippling and color coding have been eliminated.
Dimensions: 24.4 × 24.4 cm.
Condition: Pasted near the left edge; intact.
Technique: Uninked horizontal, vertical, and diagonal axes of symmetry converge at the center of the composition. Neither the orthogonal grid of squares and rectangles nor the radial construction lines seen in cat. nos. 3 and 27 have been indicated, suggesting that the pattern was copied from a model.



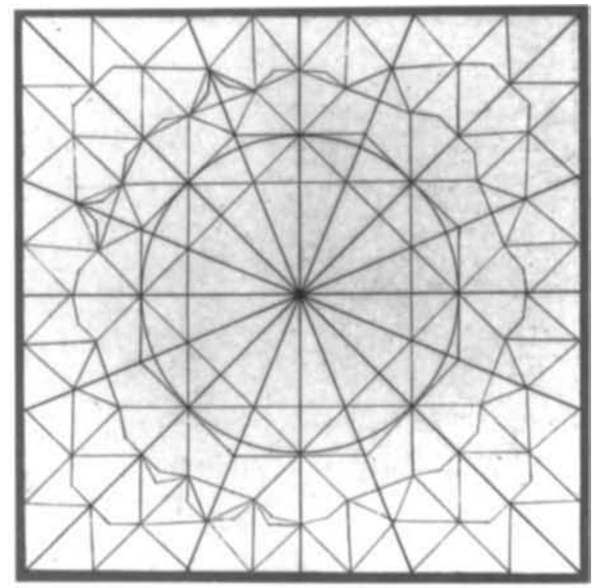
97.
Subject: Stellate muqarnas vault for a full square bay based on a composite orthogonal and radial grid system. It has a central star octagon formed by two rotated squares and framed by an octagon that grows into an eight-pointed star. The four corner squares formed by extending the sides of the central square are filled with four-pointed stars containing central octagons.
Dimensions: 24.4 × 24.4 cm.
Condition: Fine.
Technique: Uninked horizontal, vertical, and diagonal axes of symmetry converge at the center of the composition. The inked orthogonal grid, formed by extending the lines of the central square, divides the repeat unit into nine compartments of squares and rectangles that guide the composition of the pattern drawn in black ink.



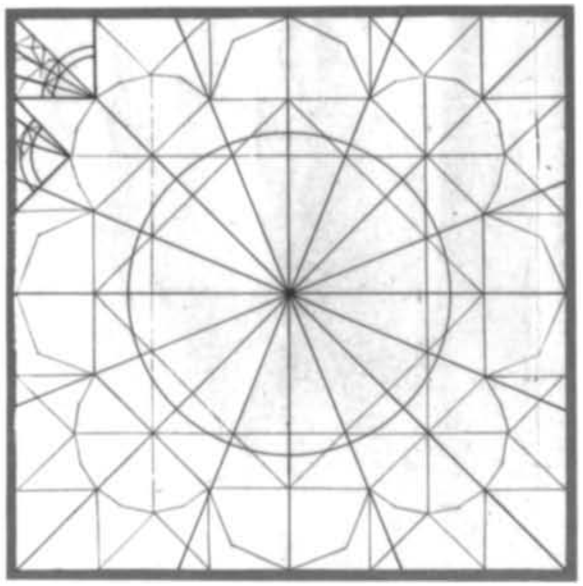
98.
Subject: Stellate muqarnas vault for a full square bay based on a radial grid system, with a central twelve-pointed star and small four-pointed stars contained in squares at each corner of the composition. The central star is surrounded by a single row of five-pointed stars interlocking with polygons and filler units.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted near the left edge; intact. Two bipeds are missing along the right edge of the repeat unit, which should have been symmetrical with the left edge. The square framing the star at the upper right corner is not fully stippled.
Technique: Uninked radial grid lines of concentric circles with twenty-four radii converging at the center of the radially symmetrical composition are surrounded by smaller subsidiary systems of twelve circles subdivided by ten radii. The corner stars are generated by uninked squares with centrally intersecting lines. The drawing is rendered in black ink and coded with black stippling to indicate the bent points of stars; the filler units are not highlighted with color coding. It presents a close parallel to cat. no. 22, which is provided with more detailed graphic information, being color coded with black and red ink, in addition to stippling.



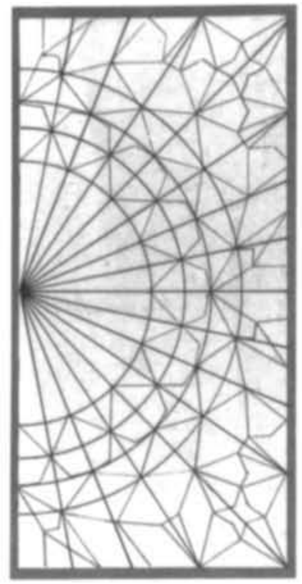
99.
Subject: Stellate muqarnas vault for a full square bay based on a composite orthogonal and radial grid system. The black-ink drawing is composed of a central rotated square, a square at the center of each of the four quadrants, and eight-pointed quarter stars in each corner. It is a nearly exact replica of cat. no. 23b with the exception of the central square. It eliminates stippling and color coding, schematically providing only the main outlines for vault compartments.
Dimensions: 24.5 × 24.5 cm.
Condition: Fine.
Technique: Uninked horizontal, vertical, and diagonal axes of symmetry converge at the center of the composition. None of the uninked construction lines seen in cat. no. 23b are included.



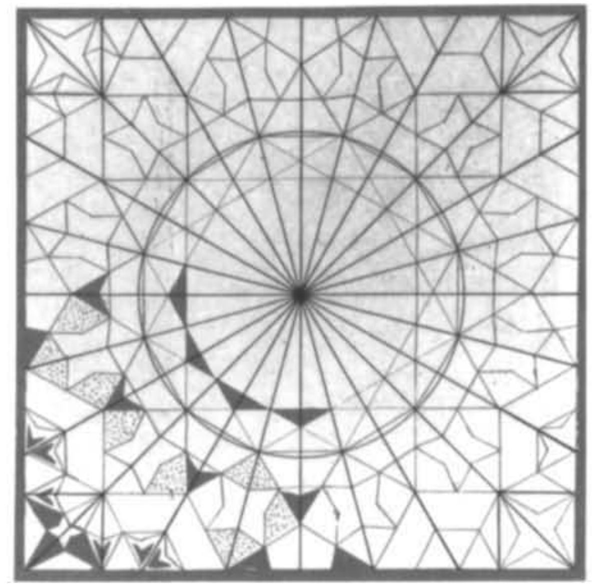
100.
Subject: Stellate muqarnas vault for a full square bay, with a central star octagon formed by two rotating squares and contained in an octagon; each corner has a square. The black-ink pattern is composed of simple polygonal compartments without stars. Some of the compartments have been fragmented by broken lines to indicate that they would have been composed of three-dimensional elements.
Dimensions: 24.7 × 24.7 cm.
Condition: Pasted along the left edge; intact.
Technique: An uninked circle with sixteen radii circumscribes the central star octagon; its radii constitute the axes of radial symmetry that guide the linear design in black ink. No other construction lines are indicated in this pattern, which is based on an implied orthogonal grid of squares and rectangles dividing the repeat unit into nine parts. The grid is formed by extending the sides of the central square up to the outer frame.



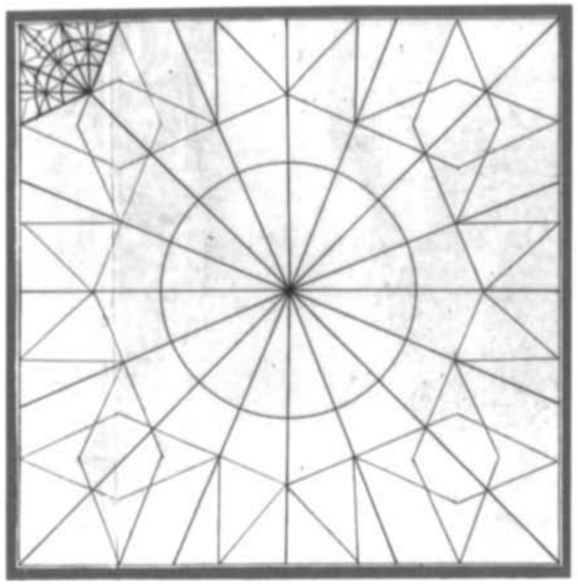
101.
Subject: Stellate muqarnas vault for a full square bay. The center is occupied with a star octagon, formed by two rotating squares, that is contained in an octagon. Each corner has an eight-pointed half star. At the upper left corner small muqarnas elements are indicated that would have been repeated in the other compartments as well.
Dimensions: 24.5 × 24.5 cm.
Condition: Pasted near the right edge; intact.
Technique: An uninked central circle with sixteen radii guides the composition. The muqarnas units at the upper left corner are generated by uninked radial grids with concentric arcs subdivided by equidistant radii. The drawing is rendered in black ink with no color coding or stippling to differentiate spatial levels. No other construction lines are shown in this repeat unit with an implied orthogonal grid of squares and rectangles formed by extending the sides of the central square up to the outer frame.



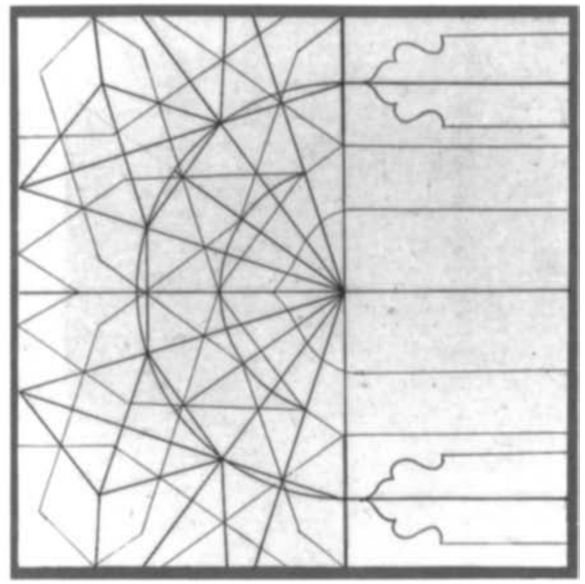
102.
Subject: Fan-shaped radial muqarnas half vault starting with rows of hexagons and arrow-shaped double bipeds featuring no intermediary row of stars; the squinch corners have four-pointed stars. Like other drawings in this part of the scroll (cat. nos. 95–105), only the main outlines of the muqarnas compartments are indicated.
Dimensions: 24.5 × 12 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric semicircles with fifteen radii (full vault would have thirty-two-fold radial symmetry) generate the design rendered in simple black-ink outlines. No stippling or color coding is used to differentiate spatial levels or to highlight filler units.



103.
Subject: Stellate muqarnas full vault for a square bay. The rotated red squares at the center form a twelve-pointed star polygon surrounded by two black-ink dodecagons, one of which grows into a twelve-pointed star interlocking with squares containing four-pointed stars and with other polygons. Each corner has a four-pointed star framed by a half octagon. The vault is composed of simple polygonal compartments framing four-pointed stars.
Dimensions: 24.5 × 24.5 cm.
Condition: Fine.
Technique: An uninked central circle with twenty-four radii generates the pattern drawn in black ink; the three rotated squares at the middle are highlighted in red ink. Only the lower left quadrant of the pattern is further subdivided into color-coded red bipeds and triangles, accompanied by stippling to differentiate spatial levels.

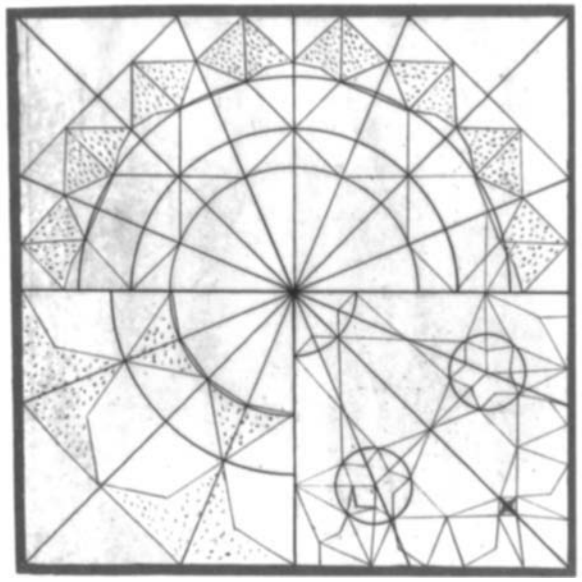


104.
Subject: Stellate muqarnas full vault for a square bay composed of simple polygonal compartments. A central octagon adjacent to triangles and four-pointed corner stars containing octagons defines the main outlines of the vault's compartments, which would have been further fragmented into tiny fan-shaped muqarnas units as indicated at the upper left corner.
Dimensions: 24.3 × 24.3 cm.
Condition: Pasted near the left edge; intact.
Technique: An uninked central circle with sixteen radii is accompanied by a secondary radial grid of concentric arcs at the upper left corner subdivided by five radii. The pattern is rendered in black ink with no stippling or color coding to differentiate spatial levels.



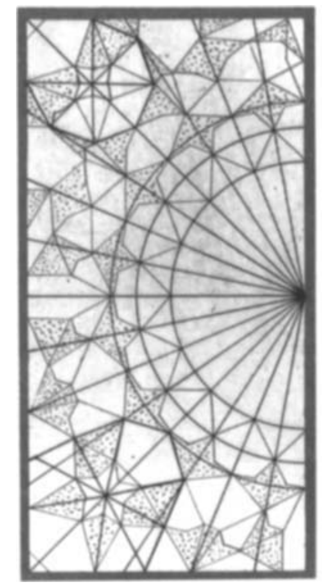
105.
Subject: Elevation drawing with three arches (a large pointed central arch flanked by smaller lobed arches) crowned by a two-dimensional star-and-polygon pattern. The components of the composition are proportionally related to one another. The design may represent a tripartite mihrab.
Dimensions: 24.5 × 24.5 cm.
Condition: Fine.
Technique: The composition is divided into four parts by two uninked intersecting axes, a vertical axis and a horizontal one passing through the springing of the central pointed arch (which coincides with the tops of the two rectangles framing the flanking lobed arches). Uninked radial grid lines of concentric arcs are drawn above the horizontal axis; their nine radii converge at the intersection of the two axes. The outermost semicircle is aligned with two uninked vertical lines that bisect the lobed arches. Other uninked construction lines include rhombuses with central crosses.

a



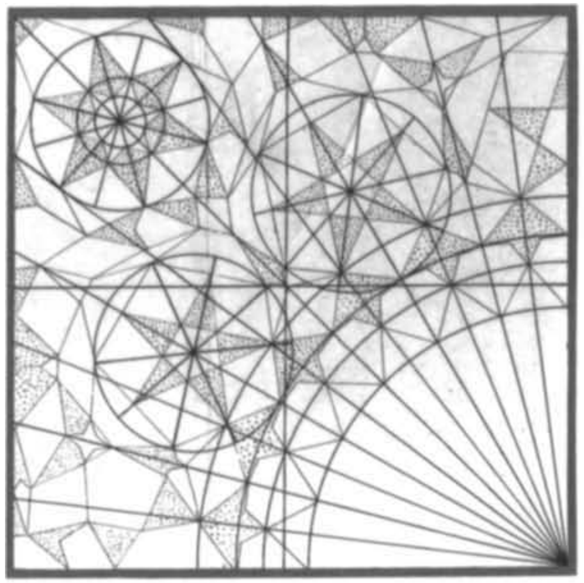
b c

106.
Subject: (a) Stellate muqarnas octagonal half vault with a central eight-pointed star, composed of simple polygonal compartments and double bipeds that do not include stars. The two other drawings, cat. no. 106b–c, that accompany this one provide alternative design options for vaulting, all of them based on sixteen-fold radial symmetry.
Dimensions: Contained together with cat. no. 106b–c in a square frame, 24.5 × 24.5 cm. The repeat unit measures 12.2 × 24.5 cm.
Condition: Pasted along the left edge; intact. Two redundant lines near the lower right corner.
Technique: Uninked radial grid lines of concentric semicircles with seven radii (full vault would have sixteen-fold radial symmetry) generate the drawing in black ink. The arrow-shaped double bipeds are highlighted with black stippling to differentiate spatial levels.
Subject: (b) Stellate muqarnas octagonal quarter vault with a central dodecagon, composed of simple polygonal shapes and bipeds with no stars.
Dimensions: 12.2 × 12.2 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked radial grid lines of concentric quarter circles with three radii (full vault would have sixteen-fold radial symmetry) generate the pattern drawn in black ink. The bipeds and double bipeds are stippled in black to differentiate spatial levels.
Subject: (c) Stellate muqarnas quarter vault with arch-net elements. An eight-pointed quarter star at the upper left corner, surrounded by a row of five-pointed stars and an elongated four-pointed star in the squinch corner. The lower left corner has been further fragmented into smaller compartments that could be extended to the whole vault if desired.
Dimensions: 12.2 × 12.2 cm.
Condition: Fine.
Technique: An uninked arc with three radii (full vault would have sixteen-fold radial symmetry) appears at the upper left corner. Two uninked circles coincide with the five-pointed stars. The design is rendered in black ink with no stippling or color coding because of the linear quality of the pattern composed of arch-net elements.

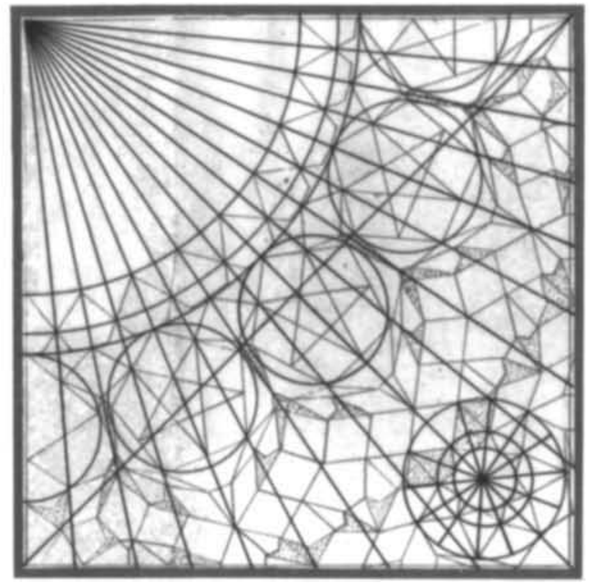


a b

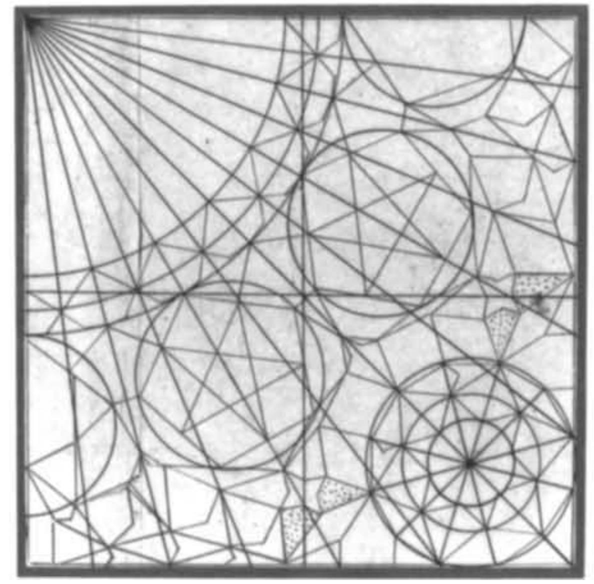
107.
Subject: (a) Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, with no intermediary row of stars; the squinch corner is occupied by a four-pointed star framed by a polygon.
Dimensions: Contained together with cat. no. 107b in a rectangular frame, 24.7 × 12.3 cm. The square repeat unit measures 12.3 × 12.3 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry) generate the black drawing whose single and double bipeds and triangular filler units are stippled in black ink, just like the two points of the corner star. An uninked polygon with eight radii generates the corner star.
Subject: (b) Fan-shaped radial muqarnas quarter vault of the same type as cat. no. 107a. Its squinch corner has a five-pointed star with one point missing.
Dimensions: 12.3 × 12.3 cm.
Condition: Fine.
Technique: Same as cat. no. 107a; here the star in the squinch corner is unbent. It is generated by an uninked irregular polygon with ten radii.



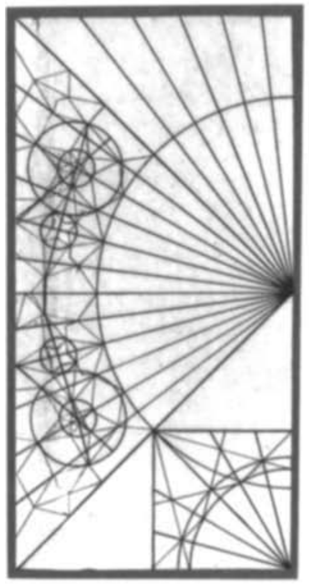
108.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars contained in pentagons, with the squinch corner occupied by a six-pointed star. Two small four-pointed stars flank the pair of five-pointed stars. The use of asymmetrical polygonal units at the bottom edge indicates that the repeat unit was meant not for a full vault but for a half vault.
Dimensions: 24.5 × 24.7 cm.
Condition: Pasted near the middle; intact.
Technique: Uninked radial grid lines of concentric quarter circles with eleven radii (half vault would have twenty-four-fold radial symmetry) and smaller subsidiary systems of circles around the unbent stars. The drawing in black ink is highlighted with stippling in black to differentiate spatial levels. Stars, double bipeds, and filler units are stippled with no differentiation, as in cat. no. 107. Uninked horizontal and vertical lines intersect at the middle of the repeat unit.

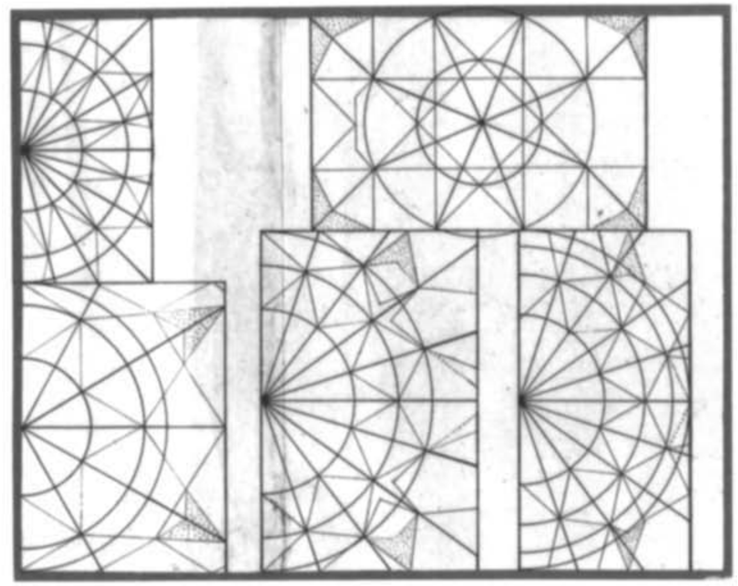


109.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a single row of five-pointed stars contained in pentagons and a continuous row of rhombuses, with the squinch corner occupied by a seven-pointed star. The use of asymmetrical polygonal units along the lower left edge of the repeat unit indicates that it was meant not for a full vault but for a half vault.
Dimensions: 24.3 × 24.3 cm.
Condition: Fine.
Technique: Uninked radial grid lines of concentric quarter circles with fifteen radii (half vault would have thirty-two-fold radial symmetry), accompanied by a row of circles and concentric circles in the squinch corner subdivided by fourteen radii. The design in black ink is highlighted with black stippling, used to mark filler units that delineate the boundaries of corbeled muqarnas tiers. The five-pointed stars inscribed in pentagons are on a single plane, unlike the seven-pointed corner star with two bent points that are stippled.



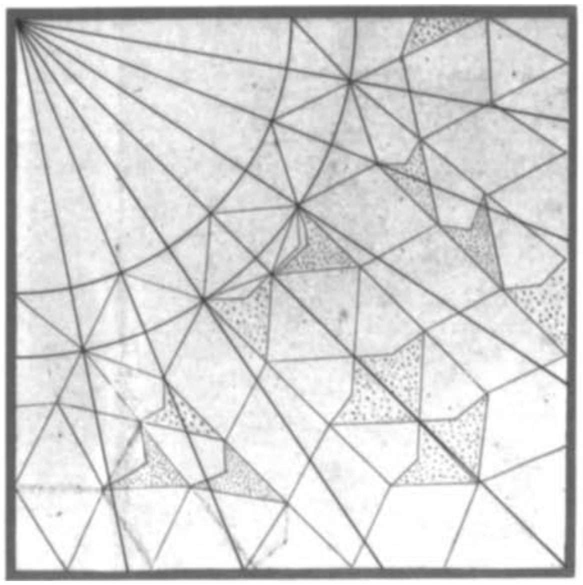
110.
Subject: Fan-shaped radial muqarnas quarter vault starting with rows of hexagons and arrow-shaped double bipeds, followed by a row of five-pointed stars contained in pentagons and another subsidiary row of four-pointed stars that flank the squinch corner with its six-pointed star. The use of asymmetrical polygonal units along the lower left edge indicates that the repeat unit was meant not for a full vault but for a half vault.
Dimensions: 24.3 × 24.3 cm.
Condition: Pasted near the left edge; intact. Five-pointed half star missing from the half pentagon along the upper right edge of the repeat unit.
Technique: Uninked radial grid lines of concentric quarter circles with eleven radii (half vault would have twenty-four-fold radial symmetry), a row of circles, and concentric corner circles with twelve radii. The black-ink drawing is stippled with black ink in only a few places; the two points of the four-pointed stars bend toward different planes, as in cat. no. 111a. No color coding is used to highlight filler units. Uninked horizontal and vertical lines intersect at the center of the repeat unit.



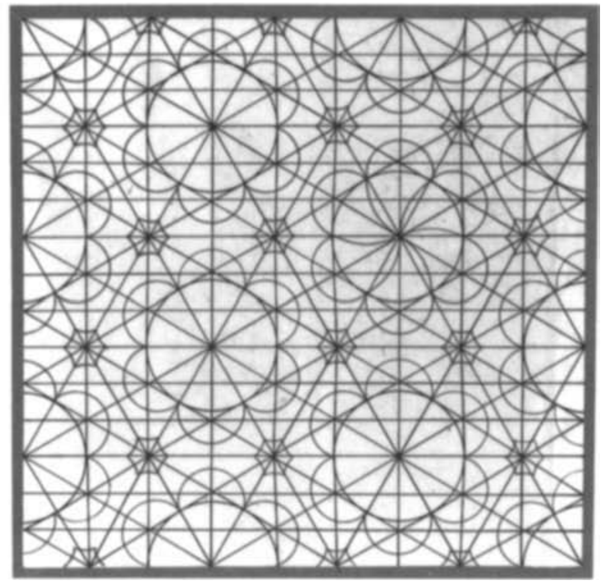


111.
Subject: (a) Triangular one-fourth repeat unit for a square stellate muqarnas vault with a central twenty-four-pointed star surrounded by a single row of alternating four- and five-pointed stars. This pattern could also be used in the triangular transitional zone of a vault.
Dimensions: Contained in a rectangle, 24.6 × 12.3 cm. The two equal sides of the triangle measure 17.4 cm.
Condition: Fine.
Technique: An uninked radial grid consisting of an arc with eleven radii (full vault would have forty-eight-fold radial symmetry) and smaller circles generates the black-ink pattern. Black stippling is used only to highlight the two points of the five-pointed bent stars, as in cat. no. 110.
Subject: (b) Stellate arch-net quarter vault with a central twelve-pointed star. It was probably meant to accompany the vault design depicted in cat. no. 111a.
Dimensions: 6.1 × 6.1 cm.
Condition: Fine.
Technique: An uninked radial grid of concentric quarter circles with five radii (full vault would have twenty-four-fold radial symmetry) generates the stellate pattern in black ink.

112.
Subject: (a) Stellate muqarnas half vault with a central twelve-pointed star surrounded by rhombuses, triangles, and corner squares.
Dimensions: Contained in a rectangular frame, 24.7 × 31.4 cm. The repeat unit measures 11.7 × 6 cm.
Condition: The large rectangle containing cat. no. 112a–c is pasted toward the middle; intact. One line (which would have made the pattern symmetrical) is missing in the lower left.
Technique: An uninked radial grid of concentric semicircles with eleven radii (full vault would have twenty-four-fold radial symmetry) generates the stellate pattern in black ink.
Subject: (b) Stellate muqarnas full vault for a rectangular space, composed of simple polygonal compartments. It has a central star octagon formed by two rotated squares extended into a second eight-pointed star, interlocking with squares and other polygons.
Dimensions: 9.5 × 15 cm.
Condition: Same as cat. no. 112a. The right and left parts of the design are asymmetrical because some lines are missing at the right side.
Technique: Uninked radial grid lines of concentric circles with eight radii generate the stellate drawing in black ink, stippled with black dots at the corners and occupied by bipeds. The implied orthogonal grid of squares and rectangles that subdivides the repeat unit is not indicated.
Subject: (c) Stellate muqarnas half vault for a rectangular space. It features a central six-pointed star surrounded by simple polygonal units.
Dimensions: 12.9 × 9.3 cm.
Condition: Same as cat. no. 112a.
Technique: Uninked radial grid lines of concentric semicircles with five radii (full vault would have twelve-fold radial symmetry) generate the stellate pattern drawn in black ink. Stippling in black ink is used to highlight the bipeds.
Subject: (d) Stellate muqarnas half vault for a rectangular space, with a central ten-pointed star surrounded by simple polygonal compartments.
Dimensions: 15.2 × 9.6 cm.
Condition: Same as cat. no. 112a.
Technique: Uninked radial grid lines of concentric semicircles with nine radii (full vault would have twenty-fold radial symmetry) generate the black-ink stellate pattern. Black stippling is used to highlight bipeds, accompanied by dotted lines.
Subject: (e) A variant of cat. no. 112d.
Dimensions: 15.2 × 7.7 cm.
Condition: Same as cat. no. 112a.
Technique: Same as cat. no 112d.



113.
Subject: Fan-shaped radial muqarnas quarter vault with no stars, composed of simple polygonal compartments and bipeds.
Dimensions: 24.7 × 24.7 cm.
Condition: Fine. Some lines and stippling are missing from the design, which should have been symmetrical along the diagonal axis connecting the upper left and lower right corners.
Technique: Uninked radial grid lines of concentric quarter circles with seven radii (full vault would have thirty-two-fold radial symmetry) generate the black-ink pattern with black-stippled bipeds and triangles. No color coding has been used in this relatively simple muqarnas pattern that does not feature any stars.

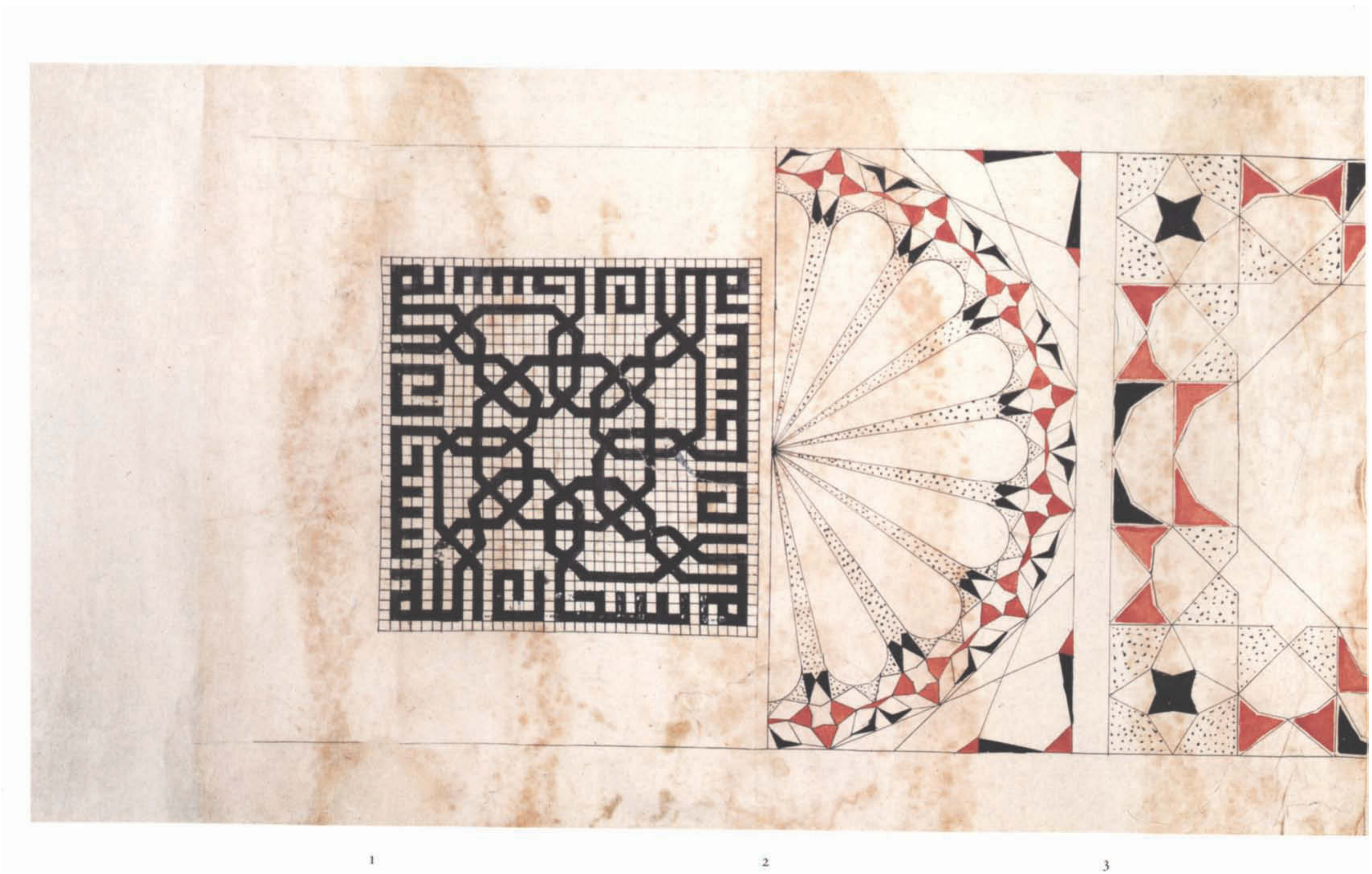


114.
Subject: Repeat unit of a curvilinear pattern in black ink based on a composite orthogonal and radial grid system. Six-petaled rosettes alternate with curved hexagons. Only one of the rosettes has curved black-ink lines intersecting at the middle.
Dimensions: 24.5 × 25.2 cm.
Condition: Pasted along the left edge; intact.
Technique: Uninked circles with twelve radii (inscribed in the six-petaled rosettes), accompanied by an uninked orthogonal grid of horizontal, vertical, and diagonal lines, generate the black-ink pattern.

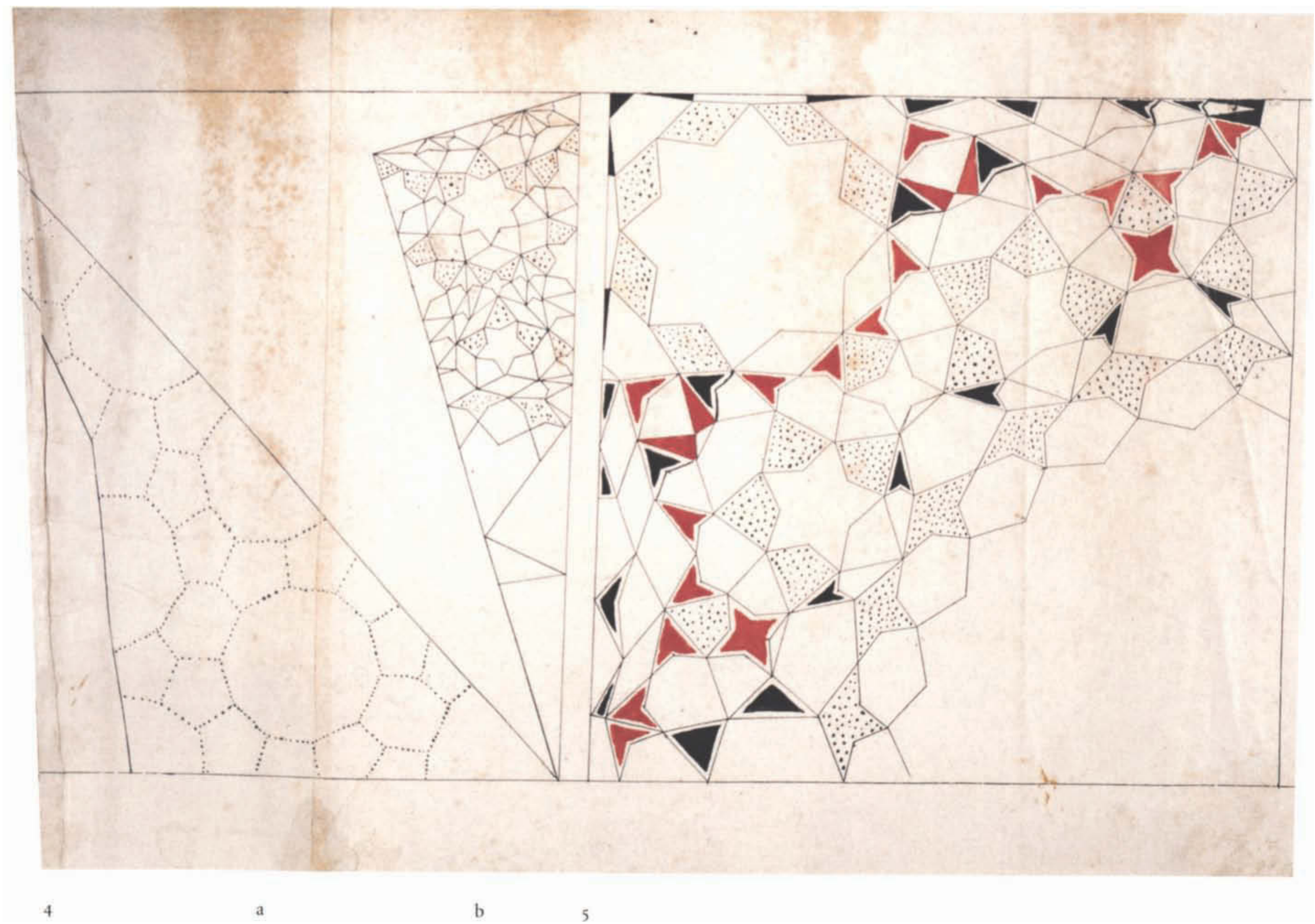
THE TOPKAPI SCROLL: A COLOR REPRODUCTION

NOTES ON THE SCROLL REPRODUCTION

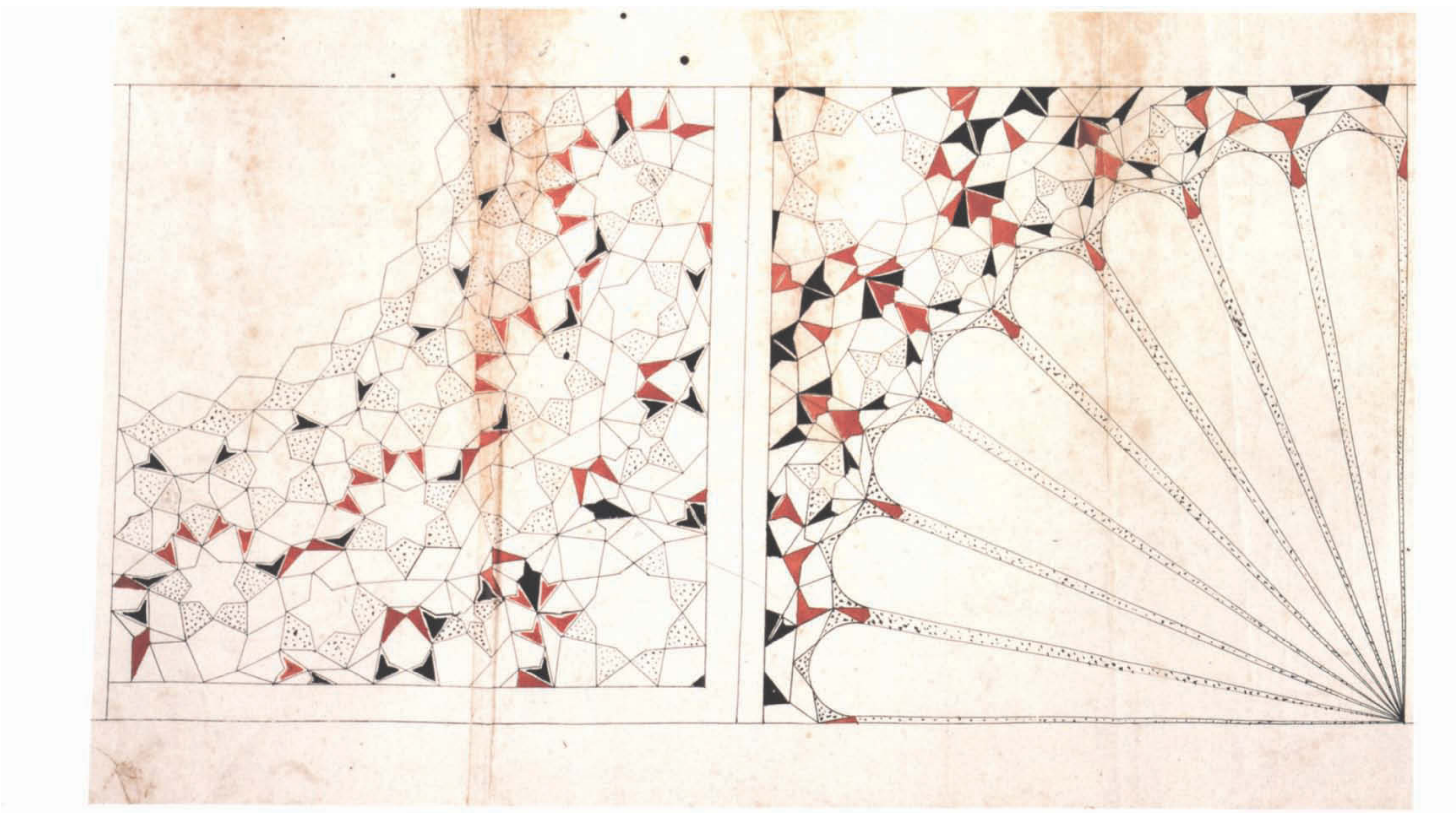
The Topkapı scroll is reproduced on the pages that follow at 50% of its actual size. In an effort to avoid adding anything extraneous to the scroll patterns or subtracting anything from them, the following parameters were observed. Only as many patterns were reproduced on a single page as would fit without crossing the book's binding (the single exception to this rule occurs in cat. no. 51, which because of its exceptional length had to be reproduced over a two-page spread). In sections of the scroll where two patterns were drawn or pasted together, the division was made along the edge of the contiguous patterns. Where an interval existed between two segments that had to be separated to continue the reproduction on the next page, this interval was bisected at the top and bottom and a division was made through these midpoints. As a result, the sides of the portion of the scroll shown on a single page are not always perpendicular, reflecting the fact that the original drawings are slightly irregular. The tattered extreme upper and lower edges of the scroll, which are well outside of the image area, have been cropped minimally to straighten them and make them parallel.



1 2 3



4 a b 5



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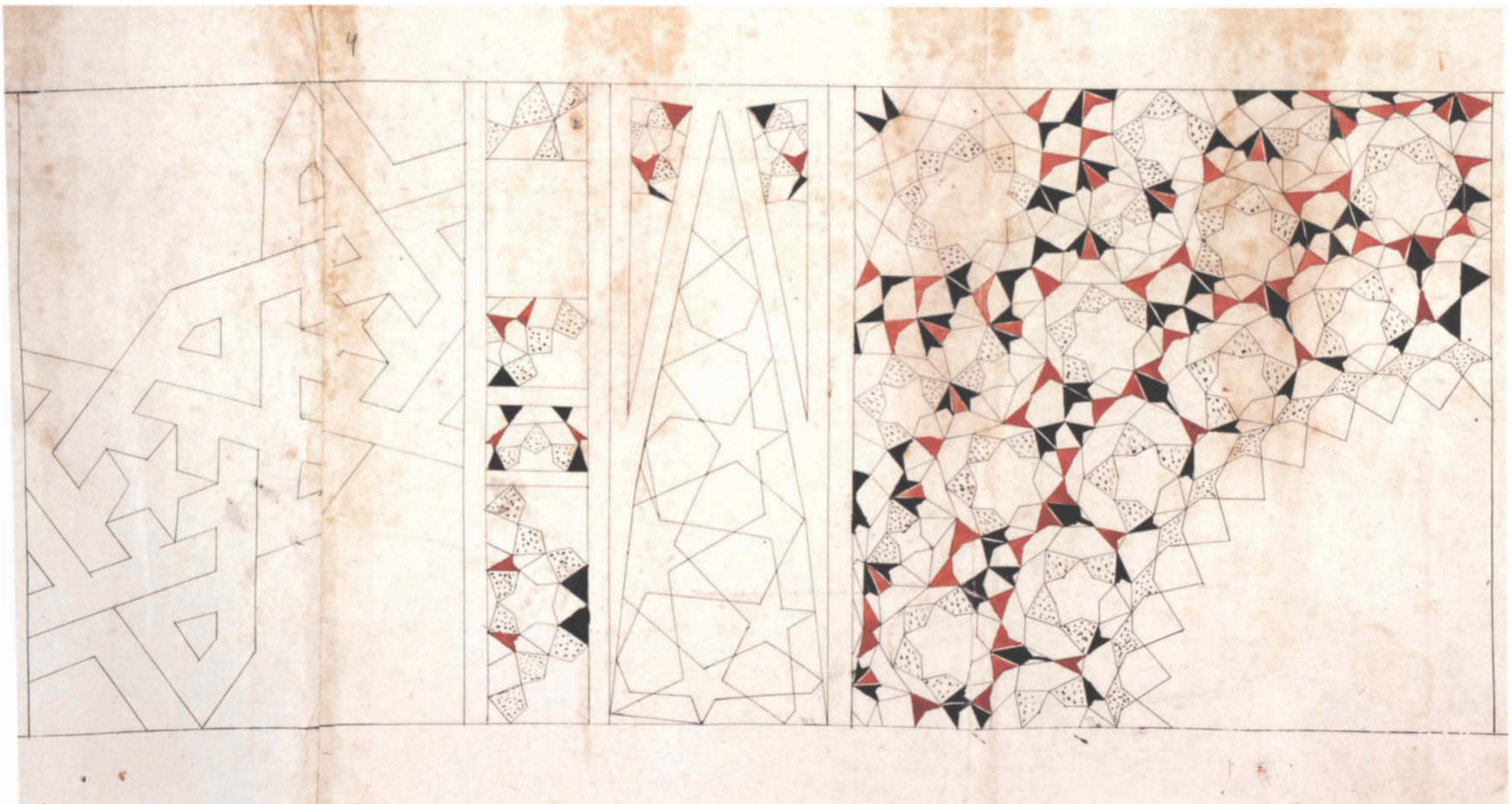
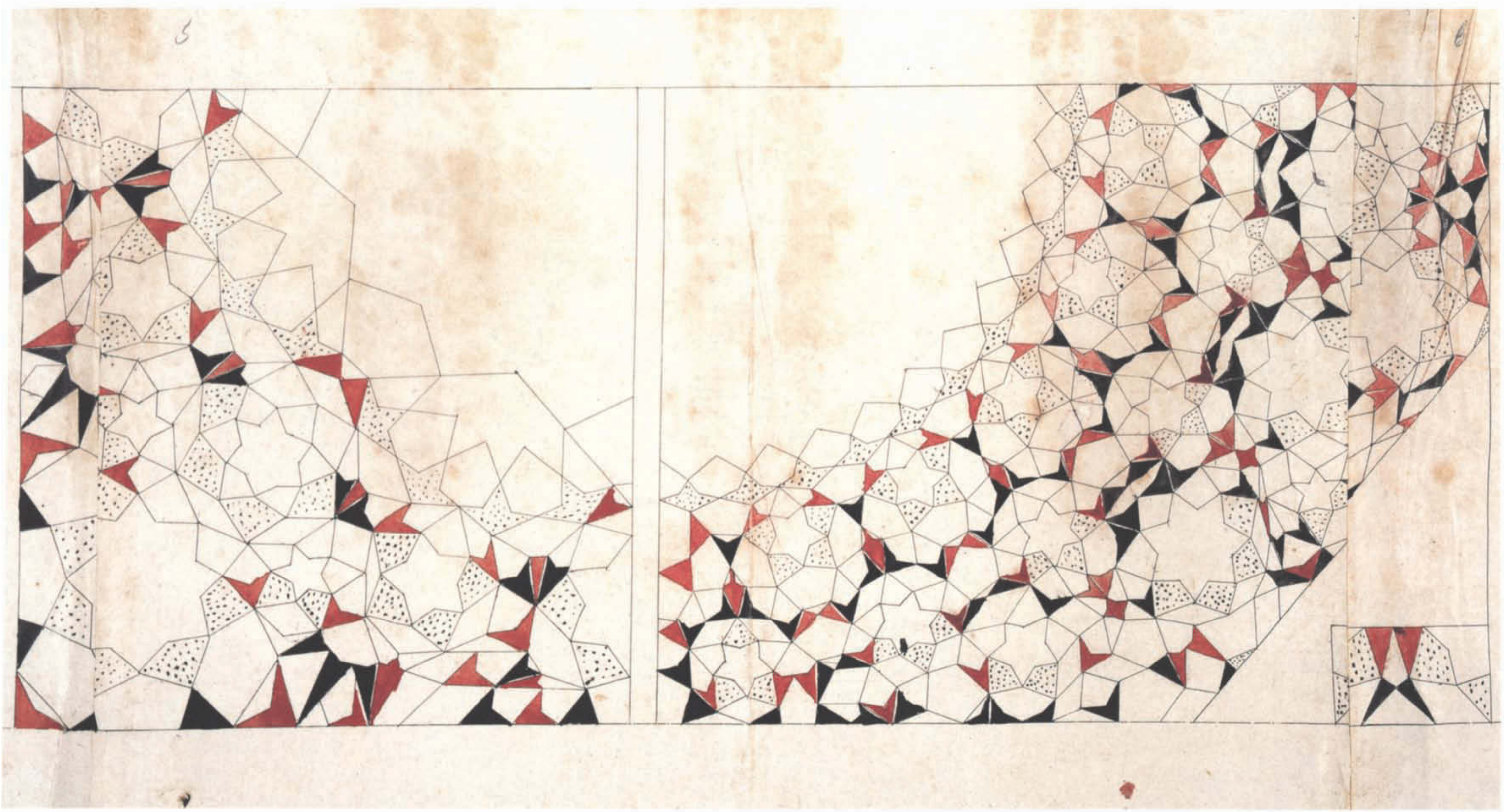
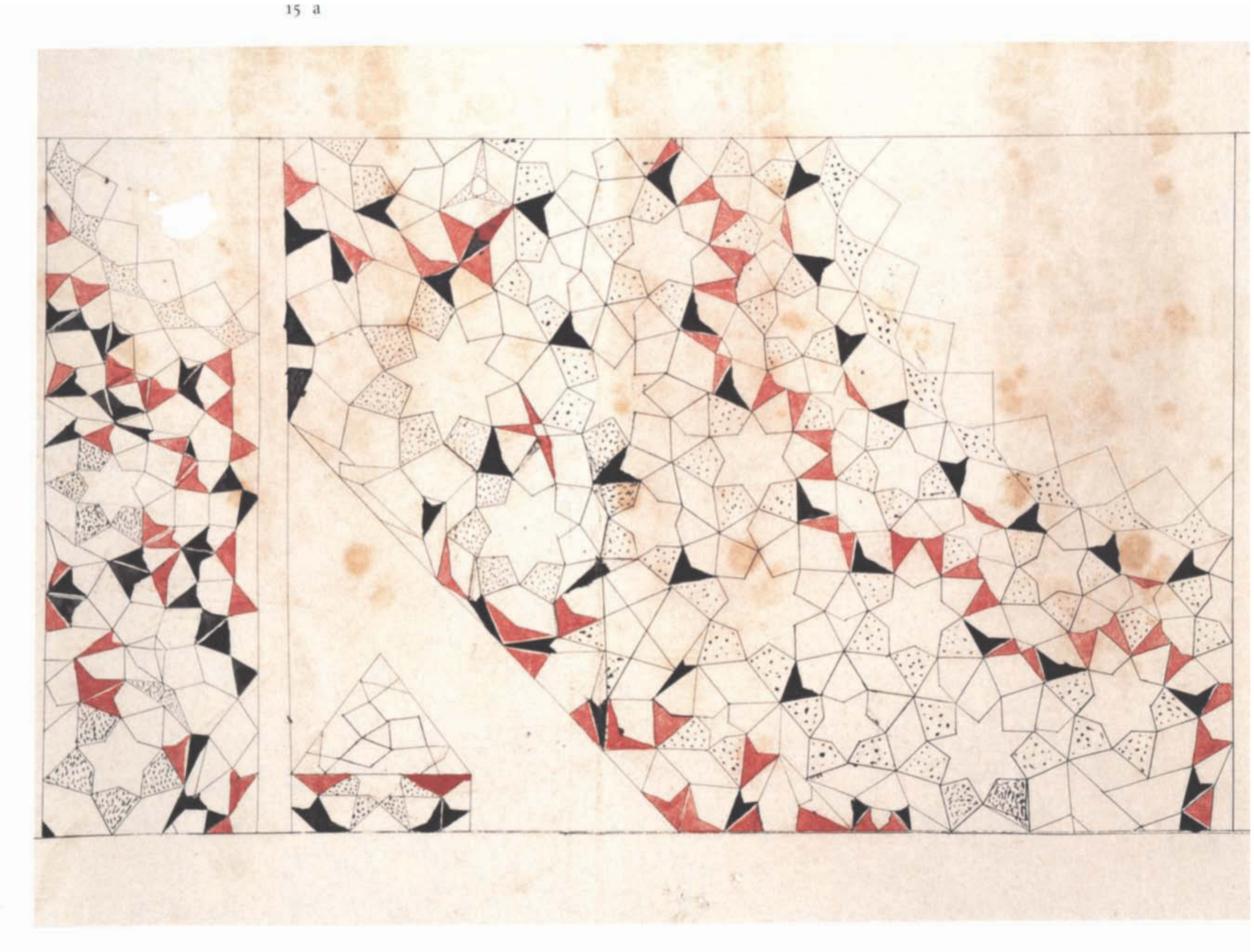


8 9 a b c d 10 a b c 11



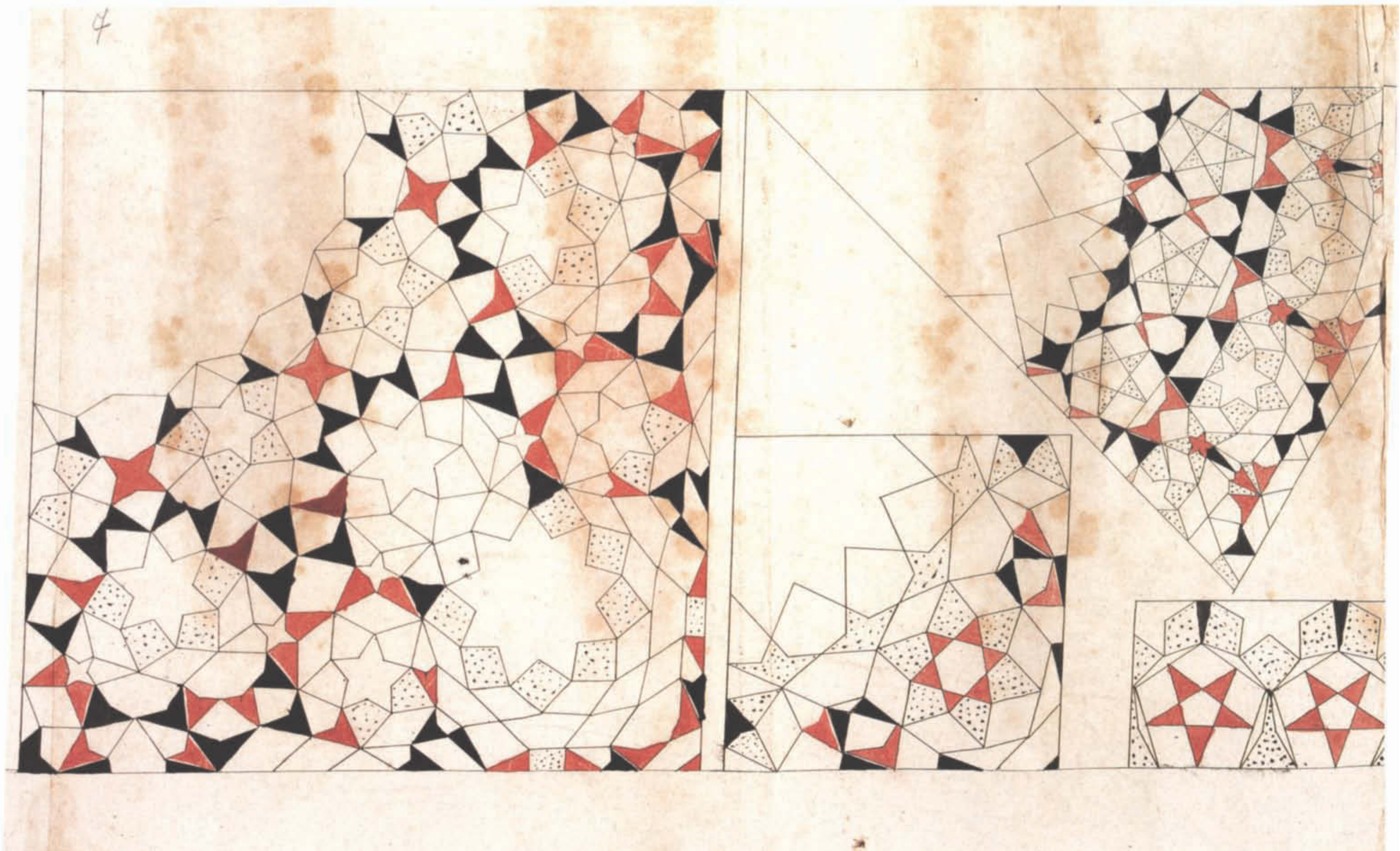
12 13 a b

15 a

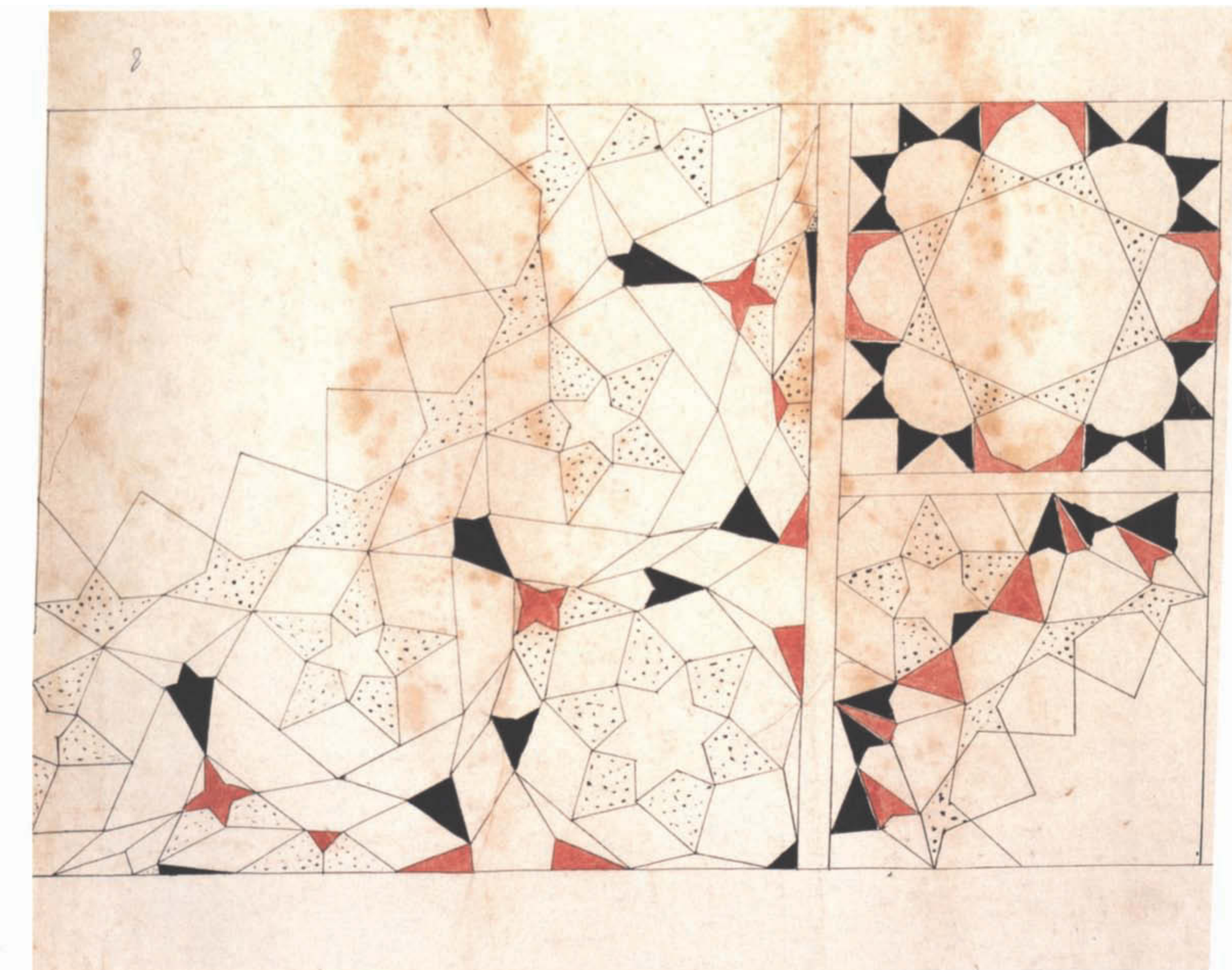


14 15 b

17 a

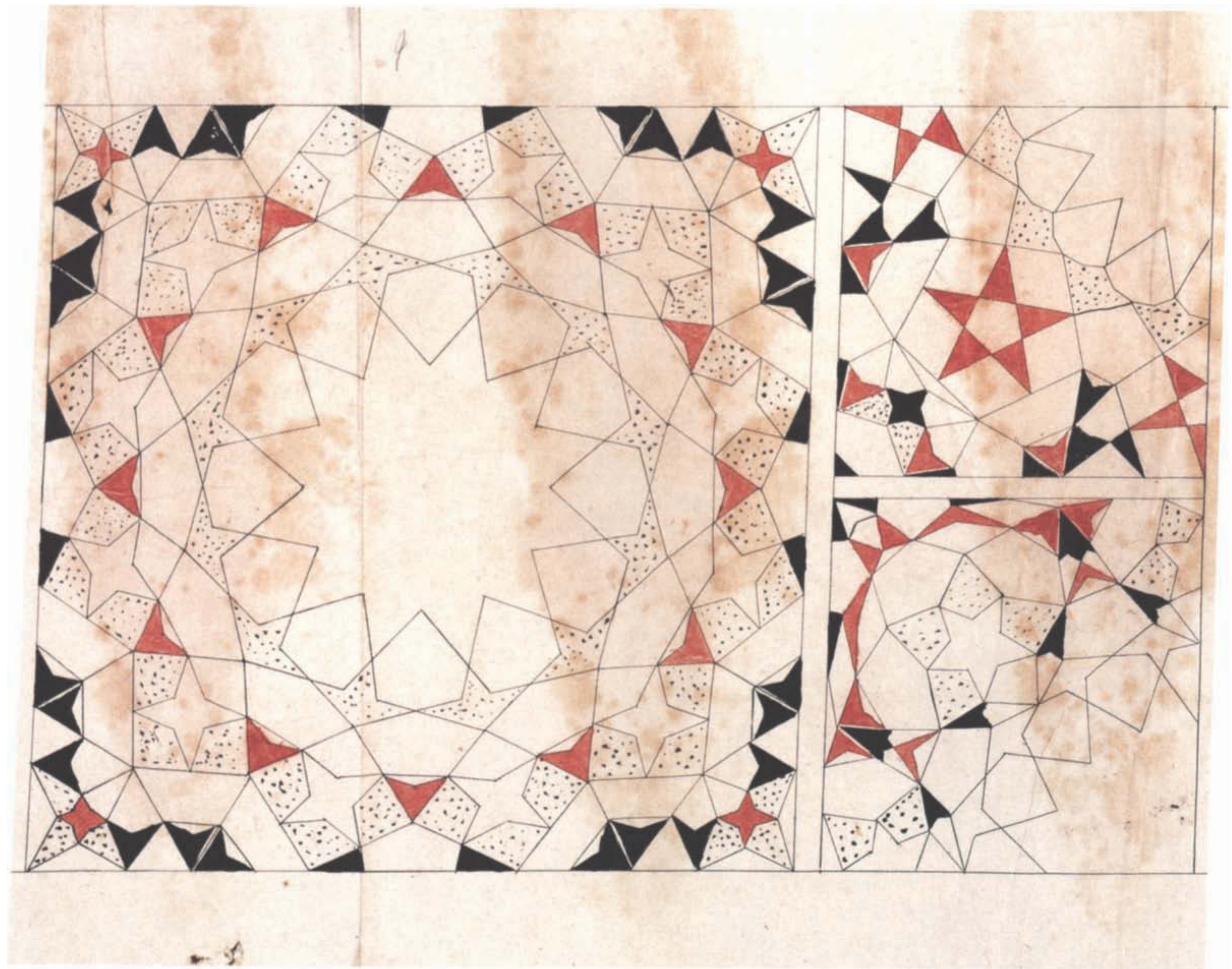


16 17 b c



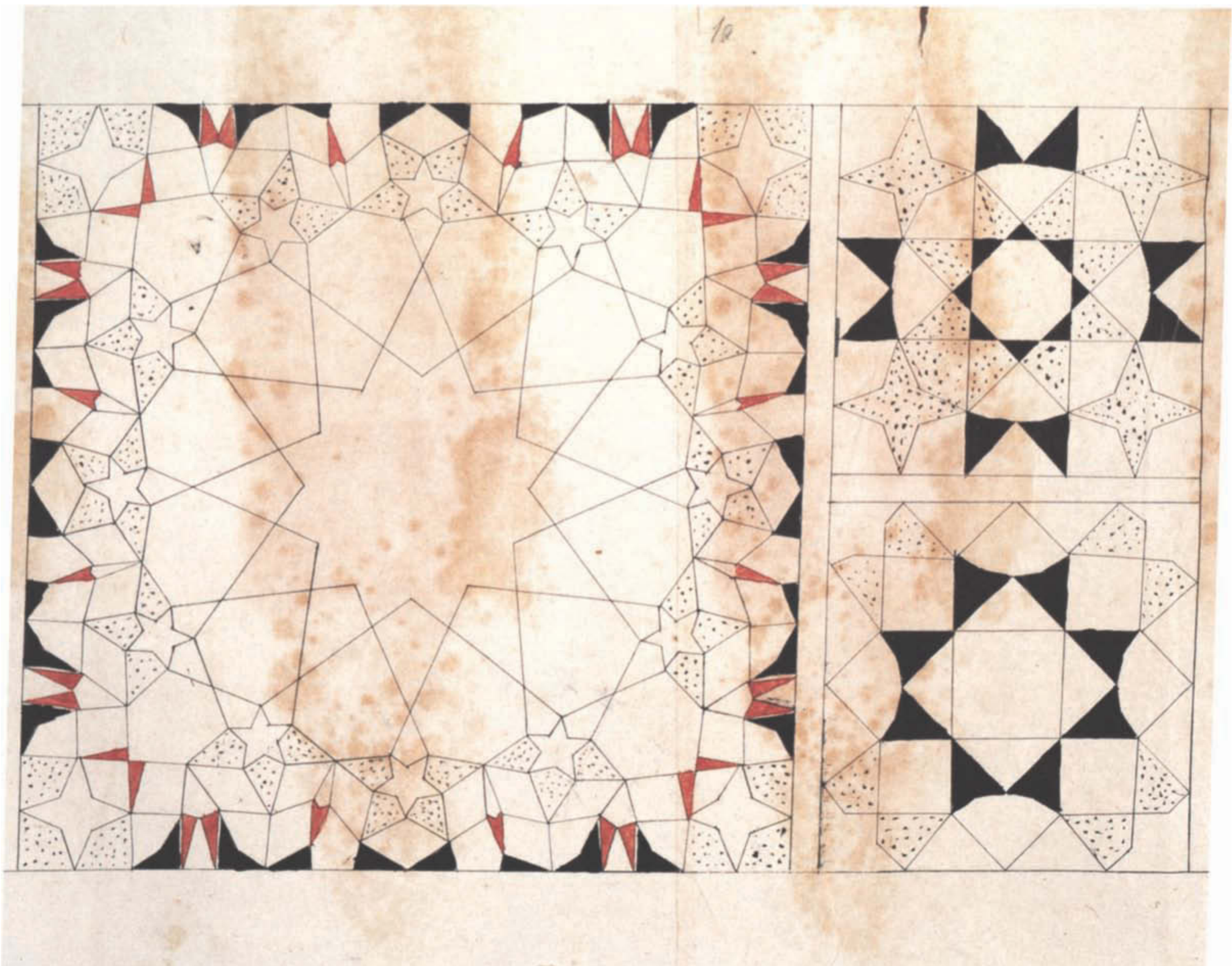
18

19 a b



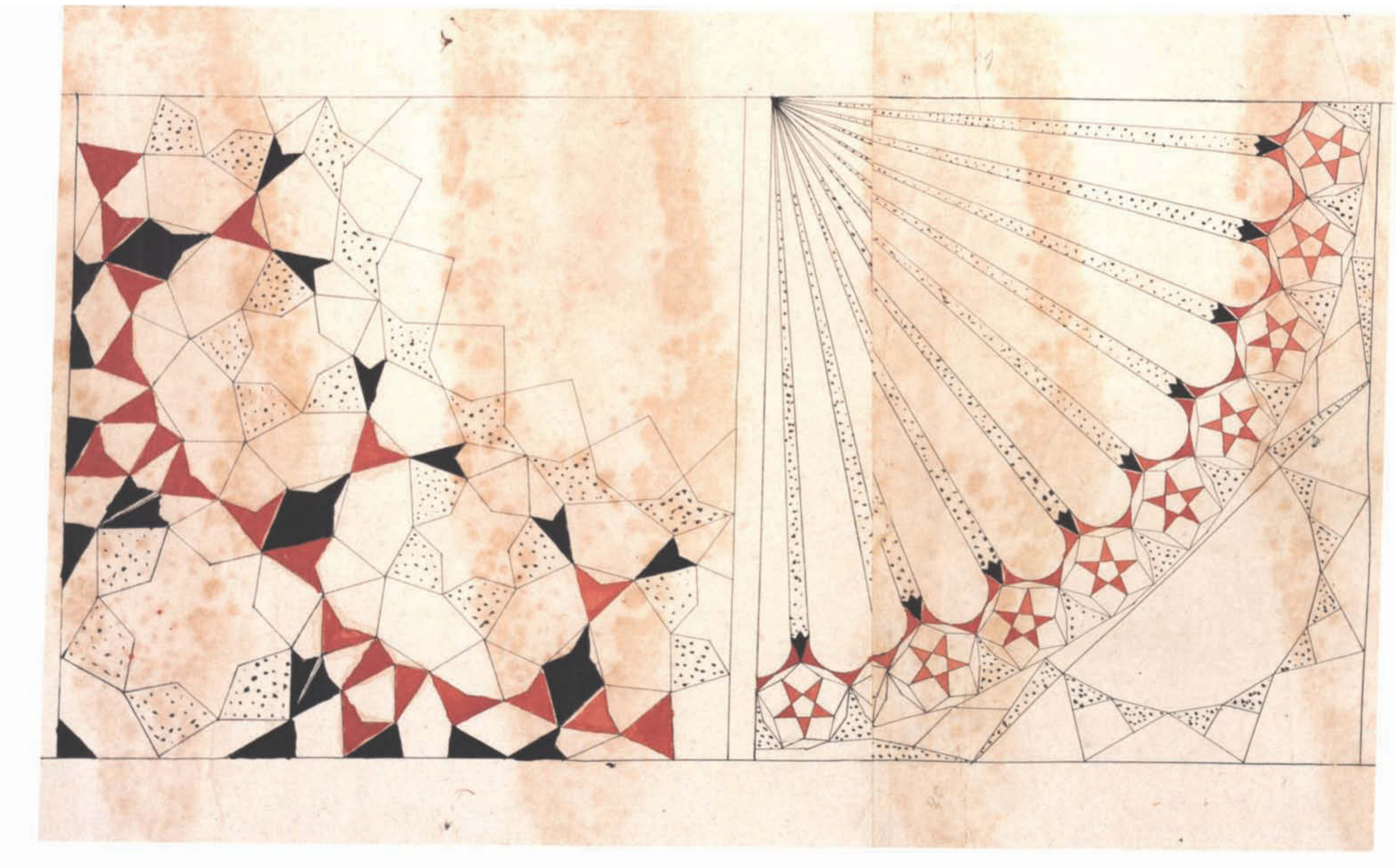
20

21 a b



22

23 a b



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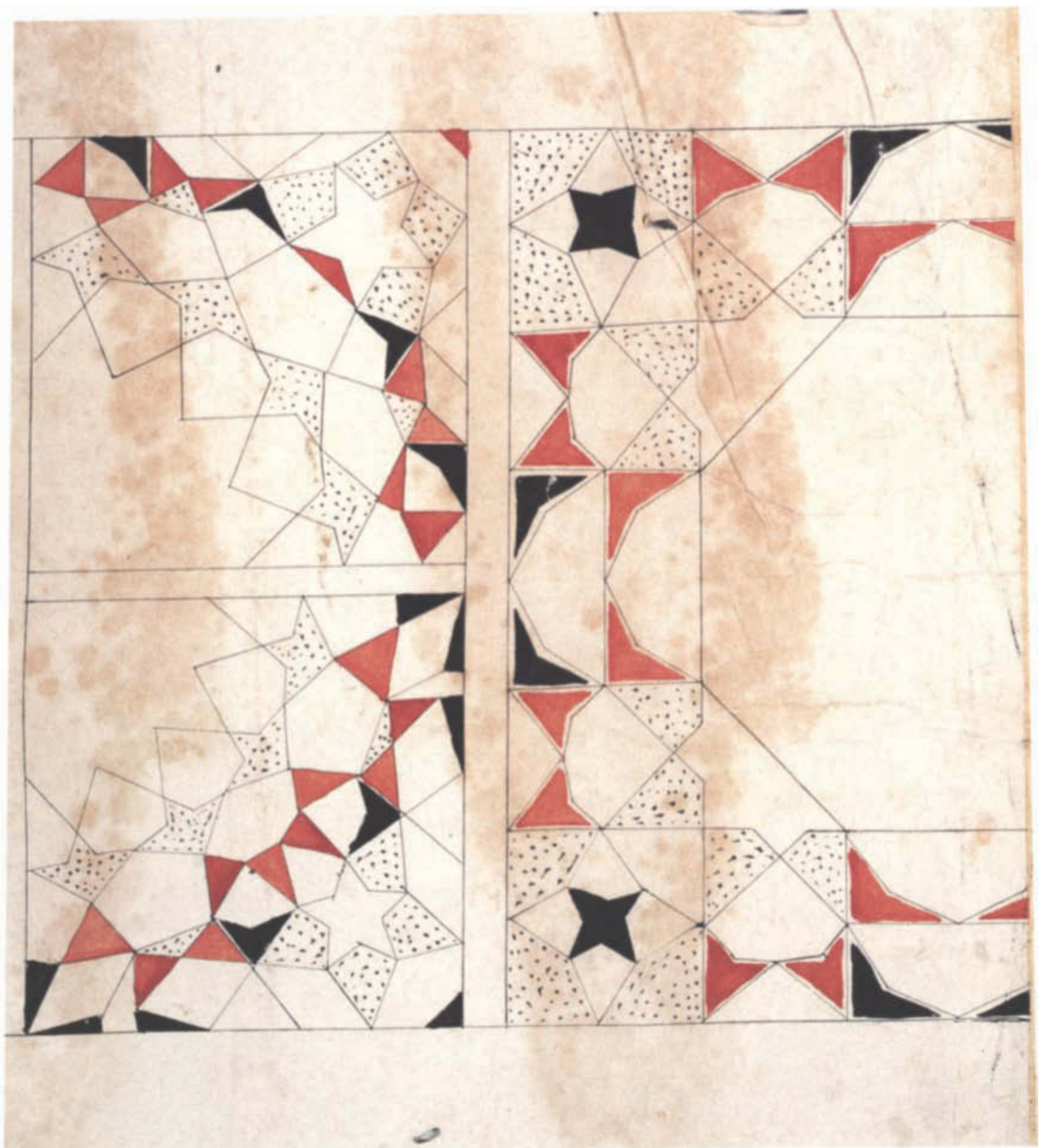
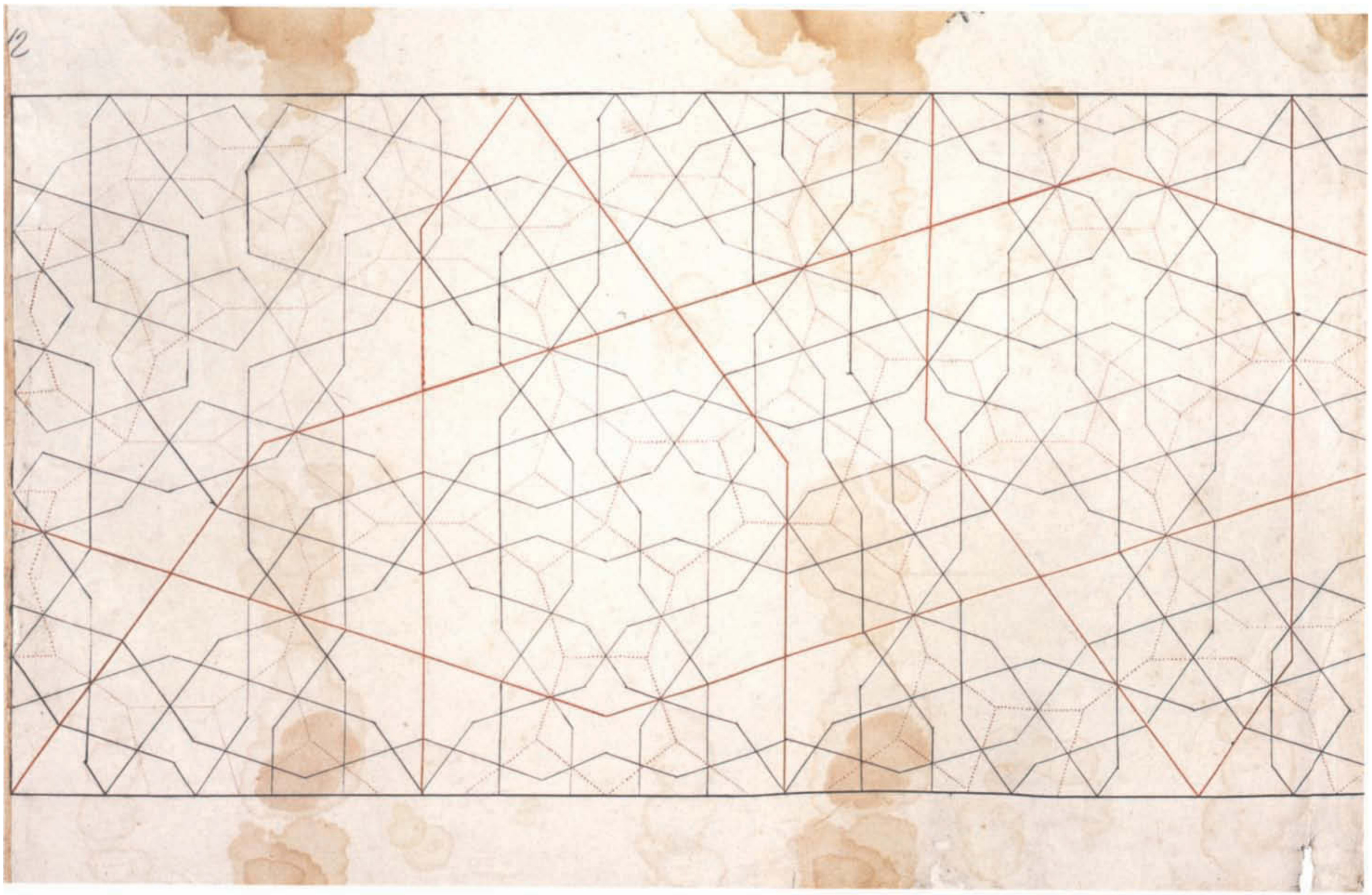
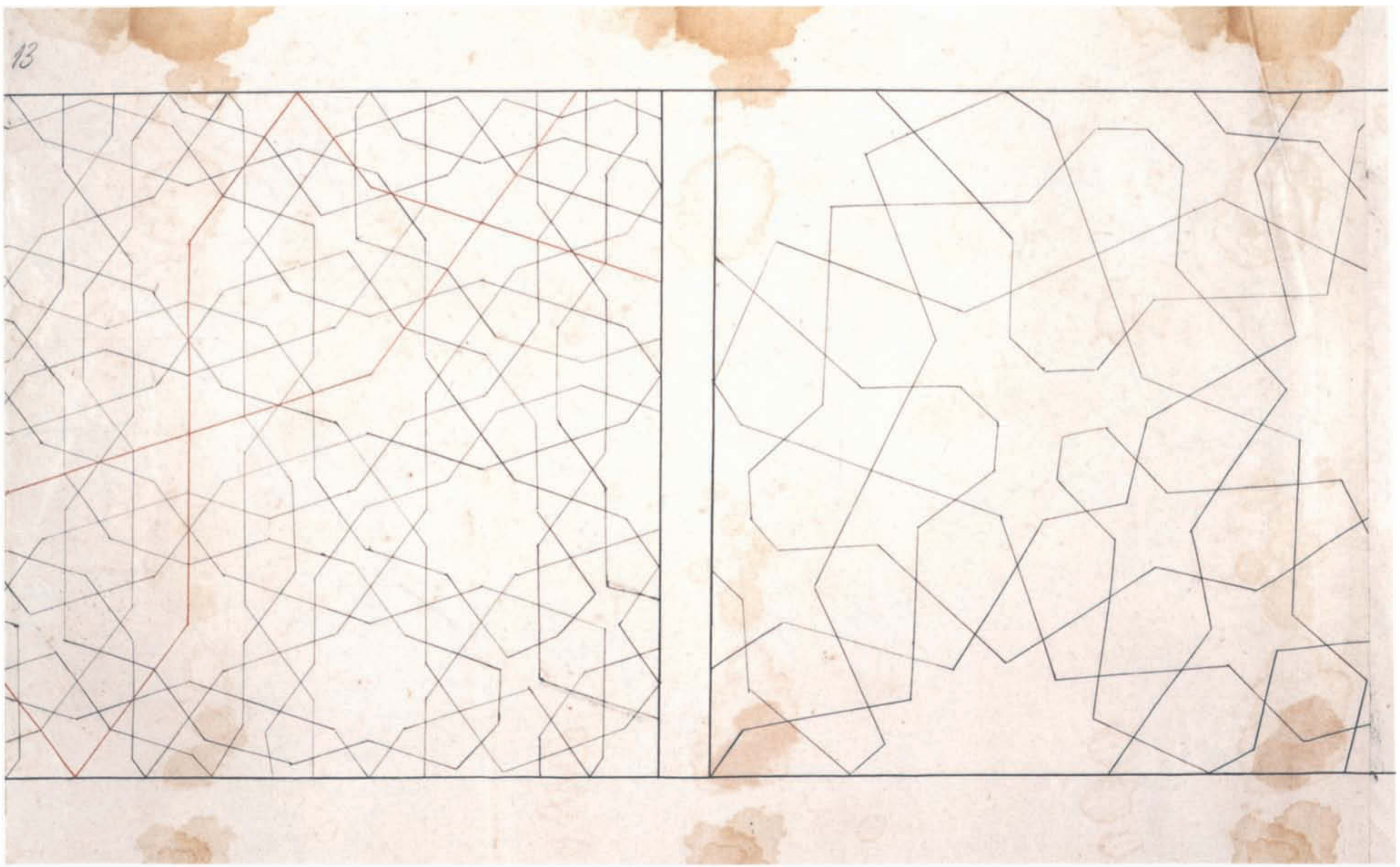


26 a b 27



28



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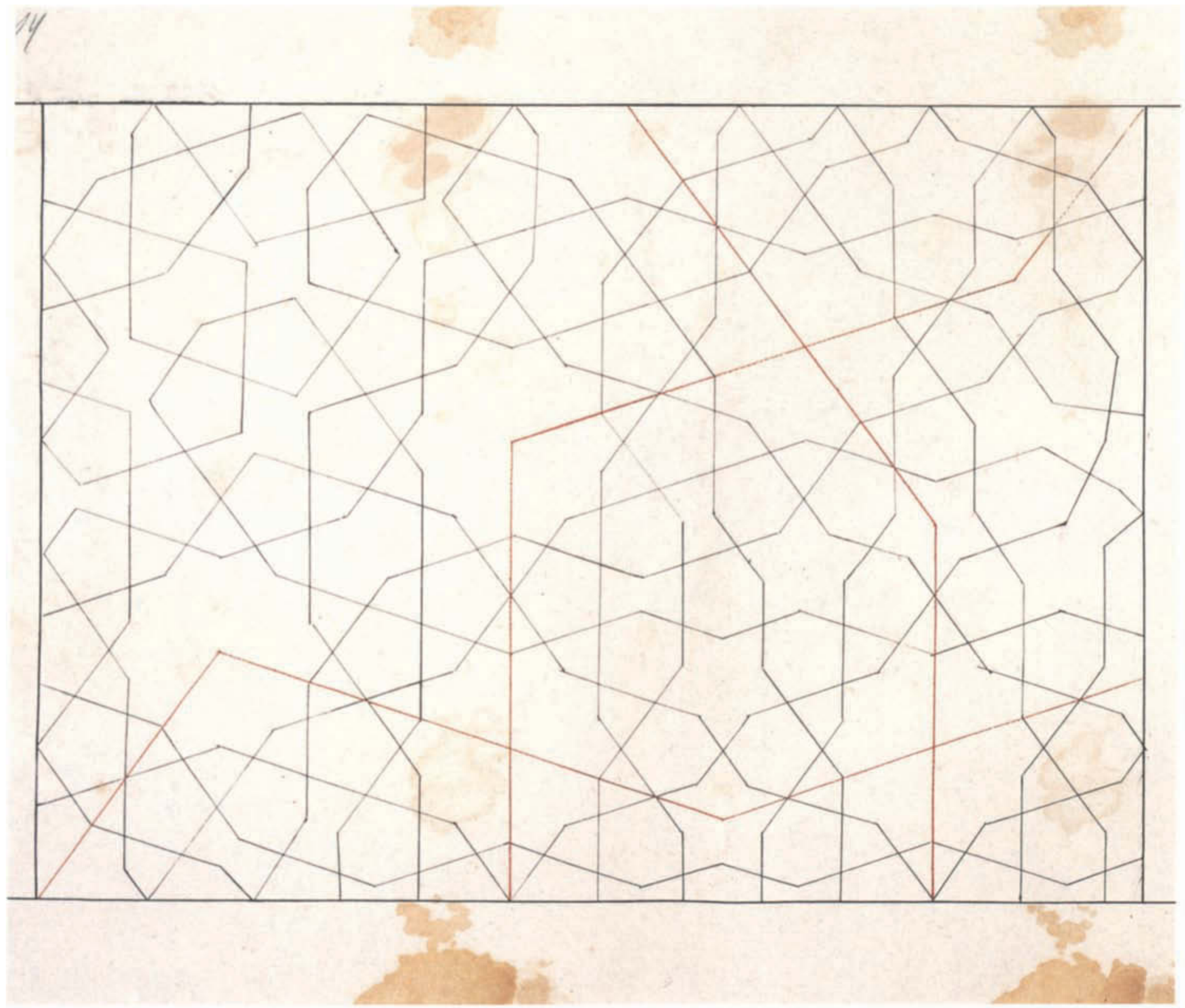

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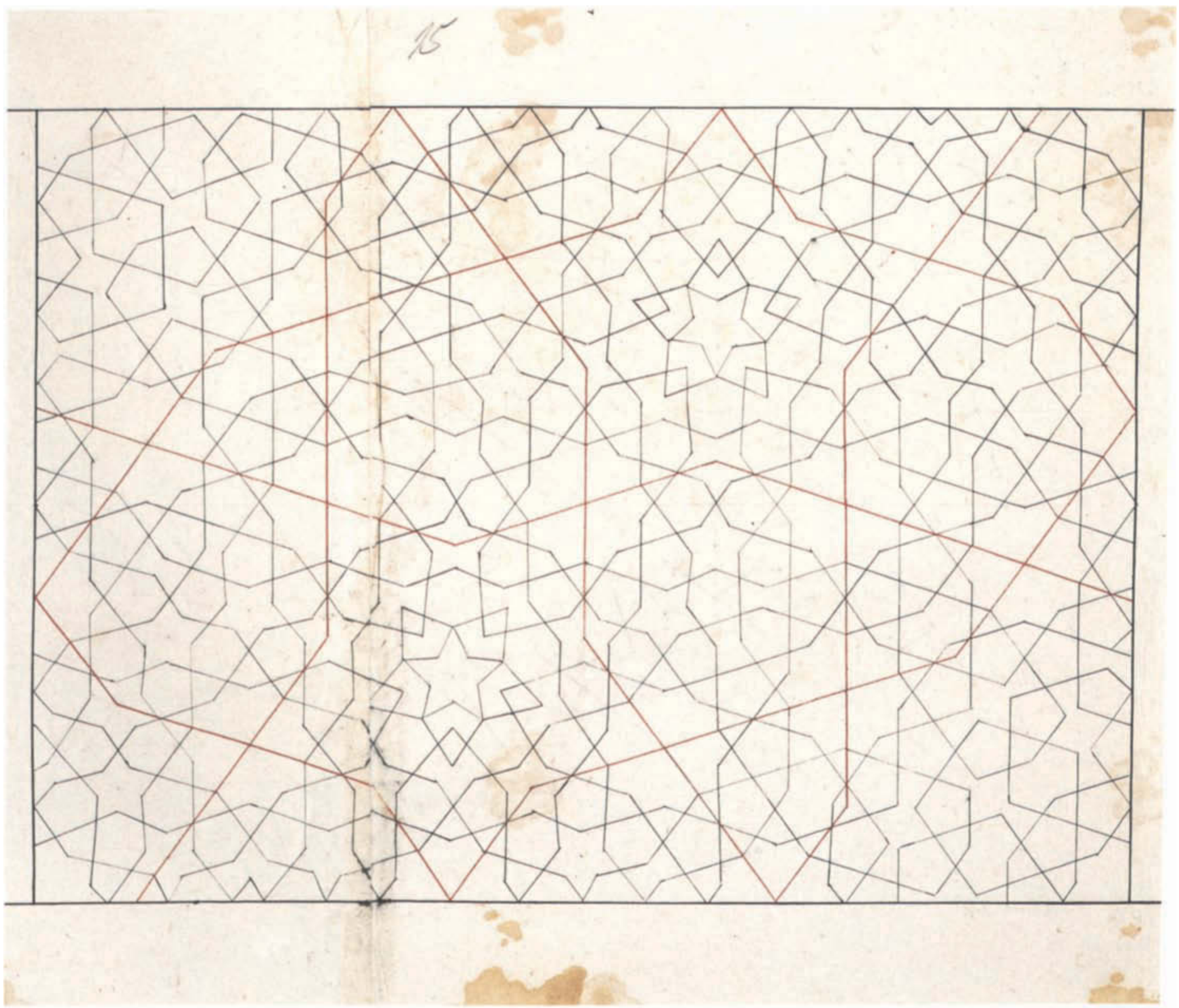

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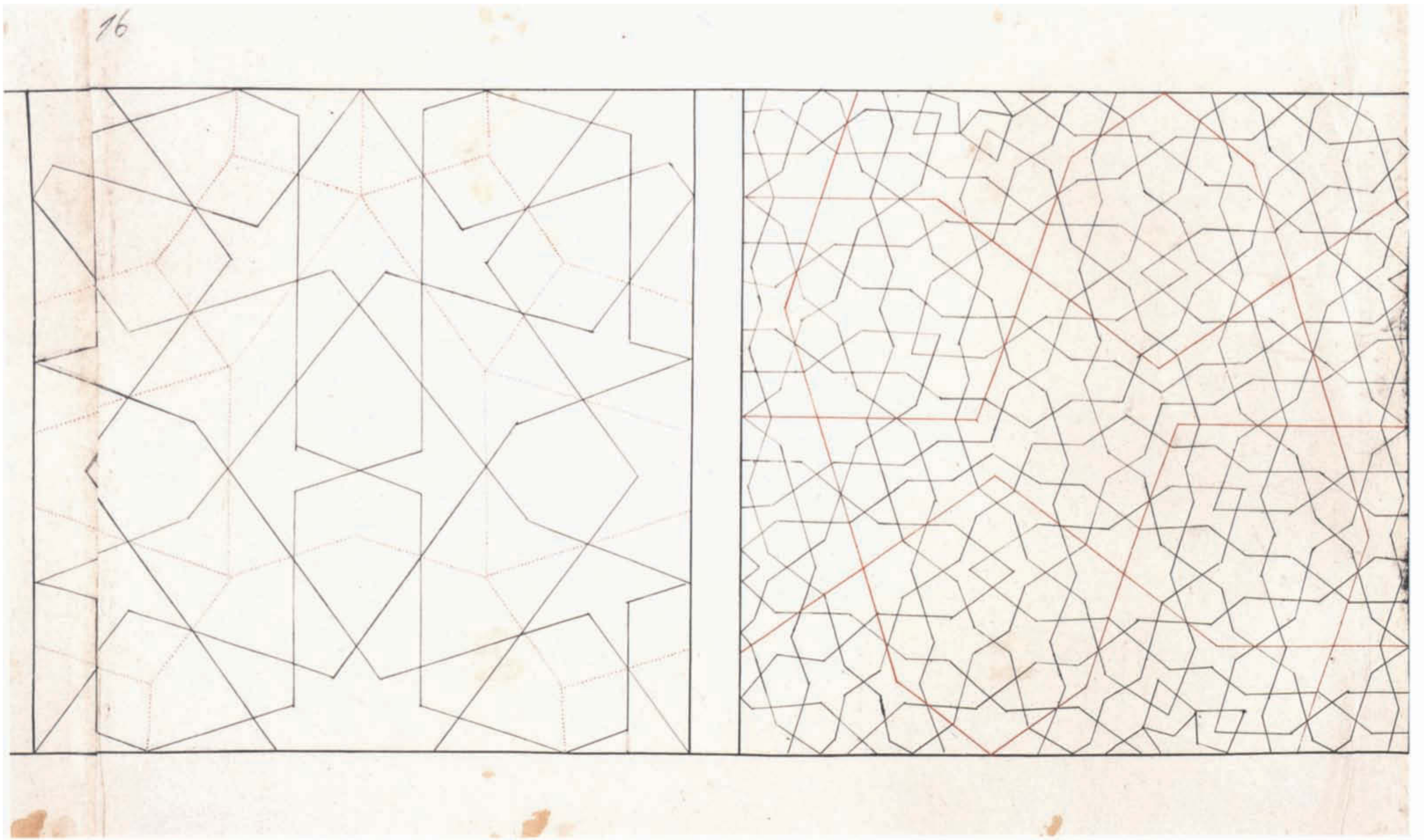

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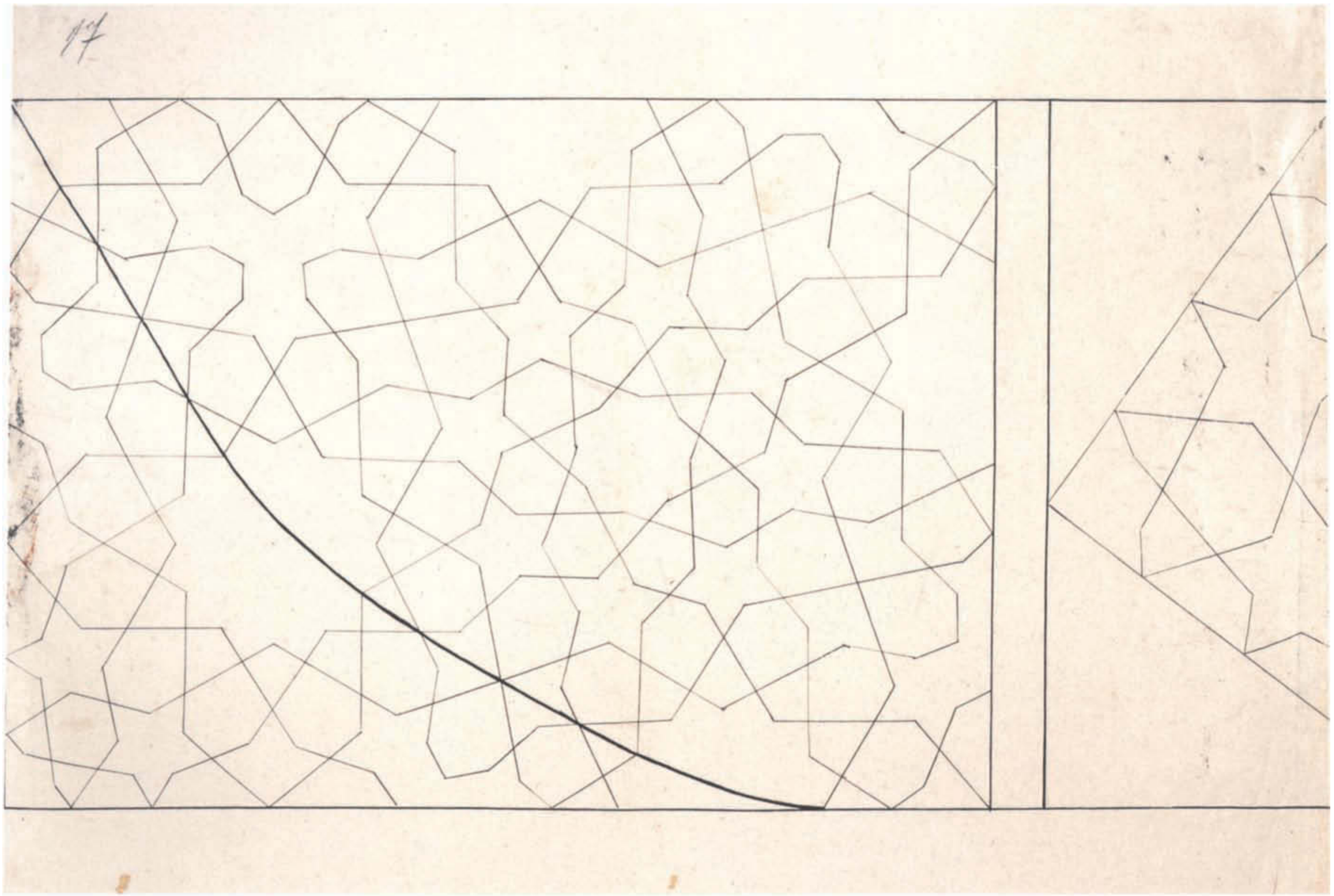

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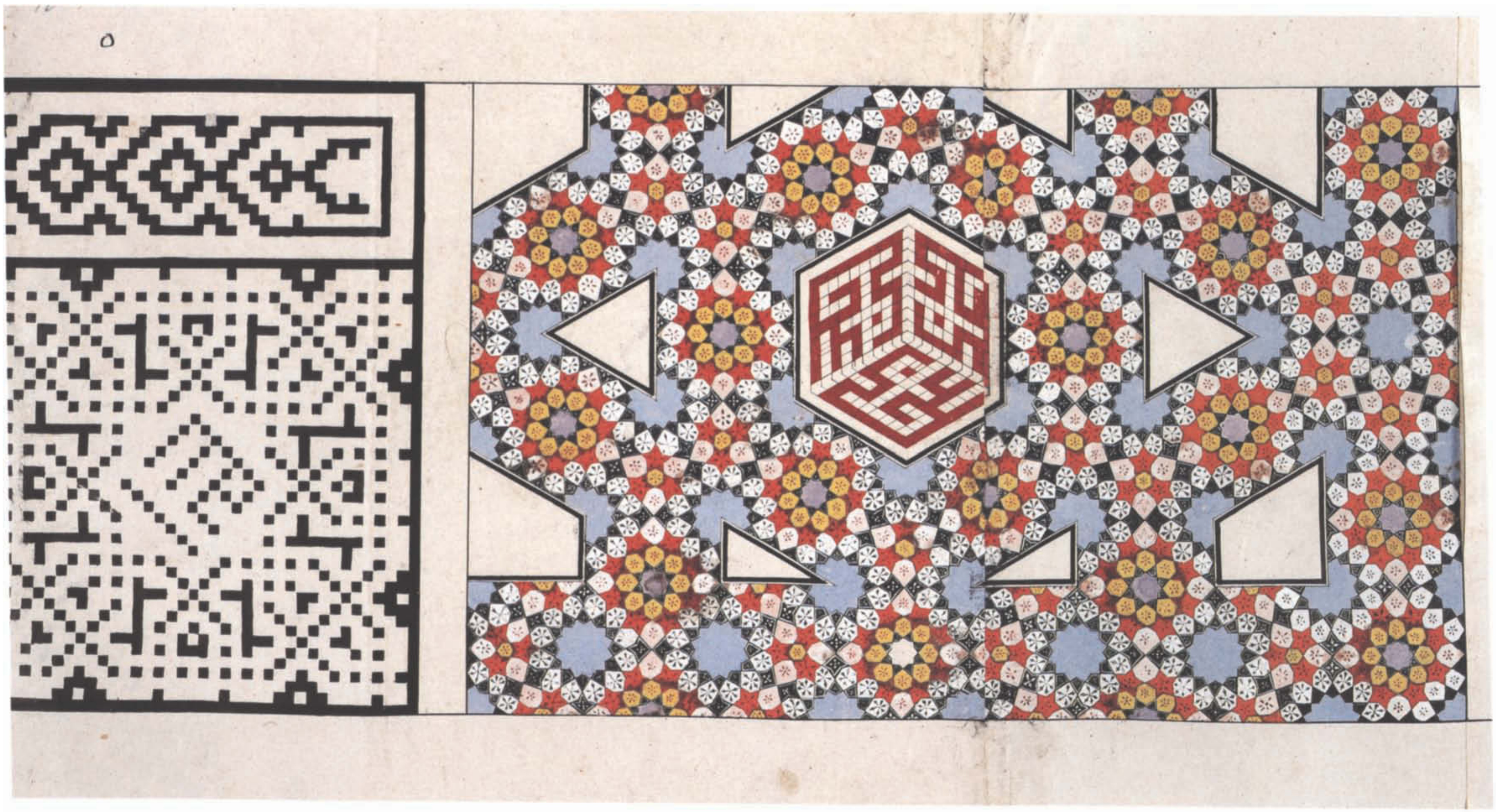

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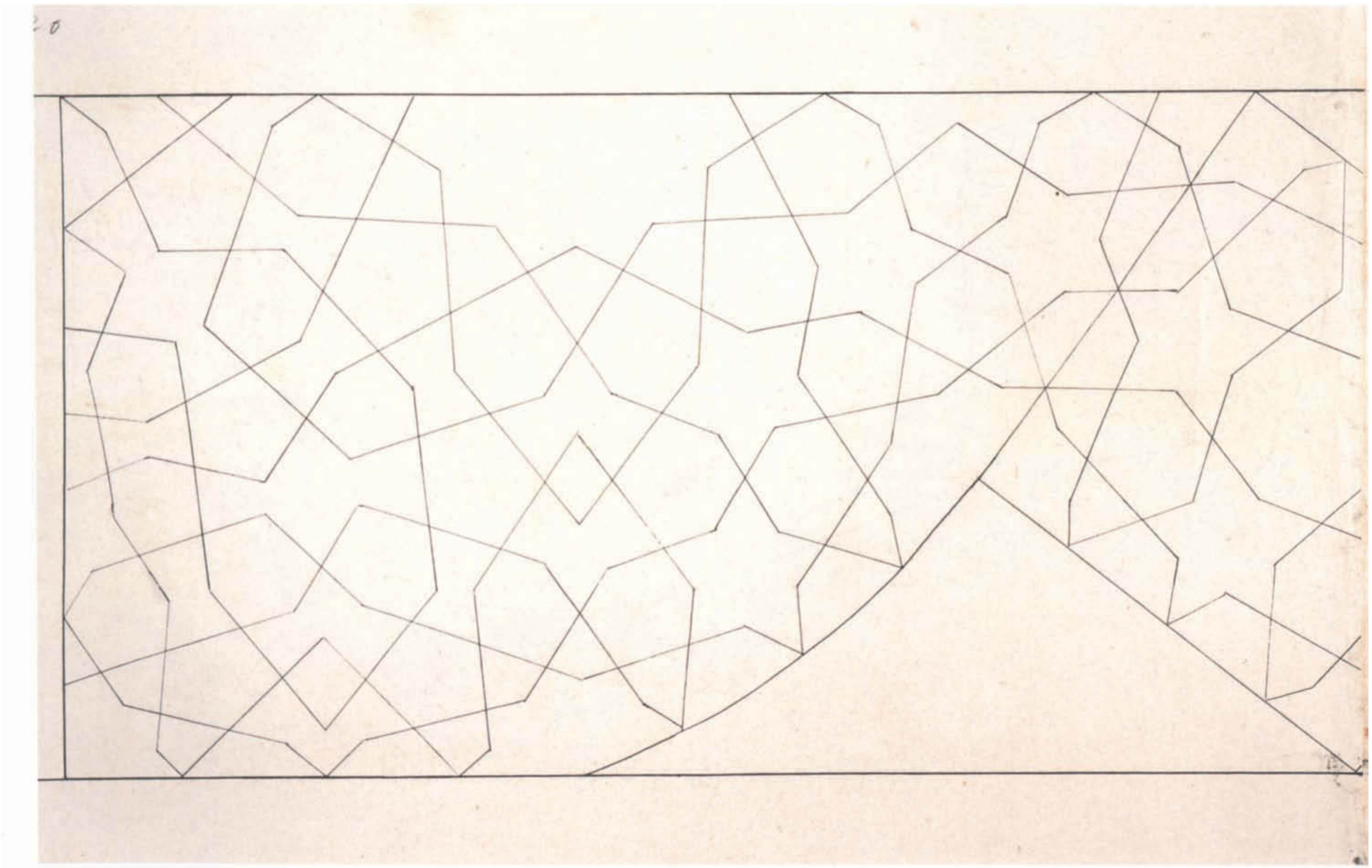

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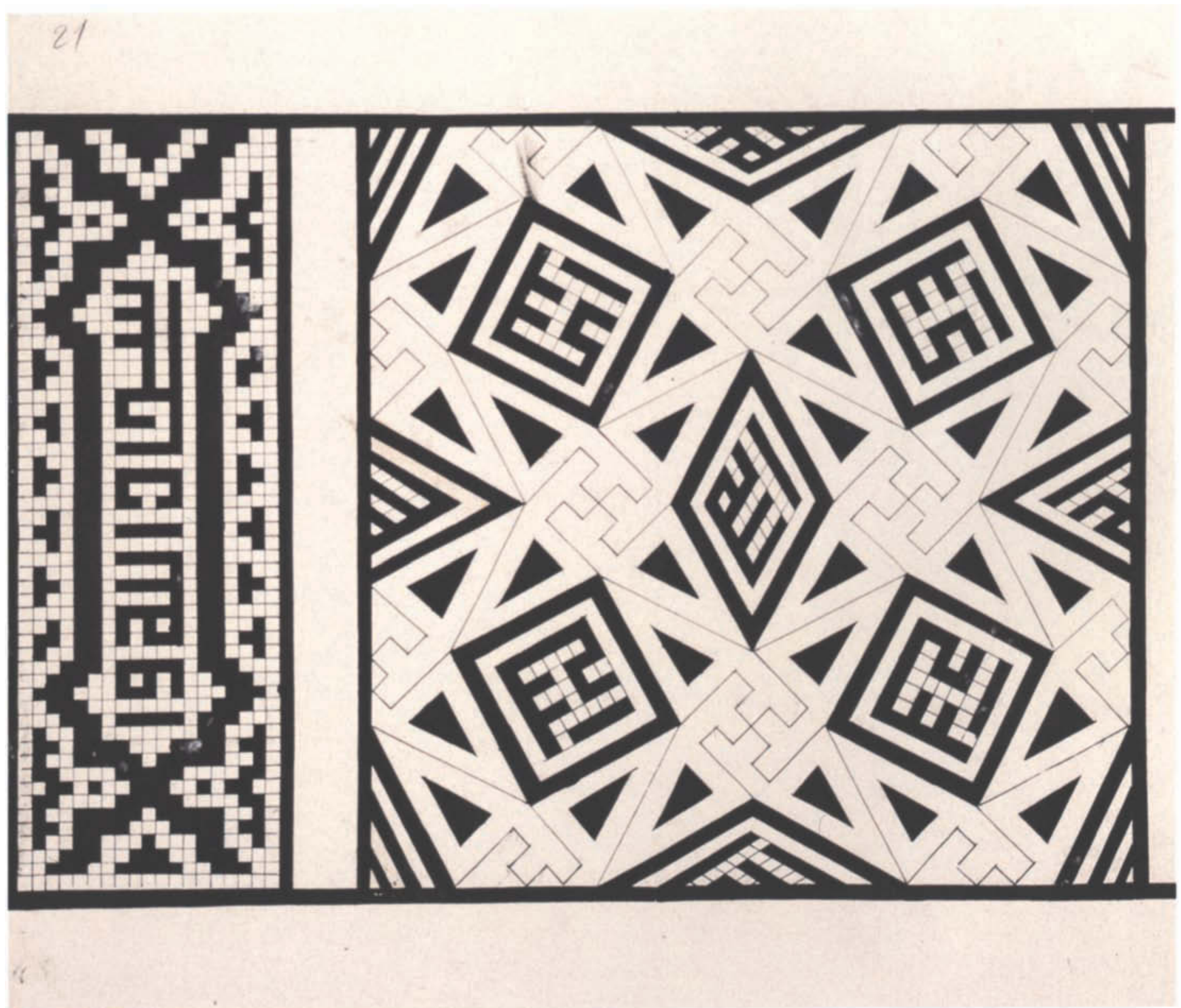

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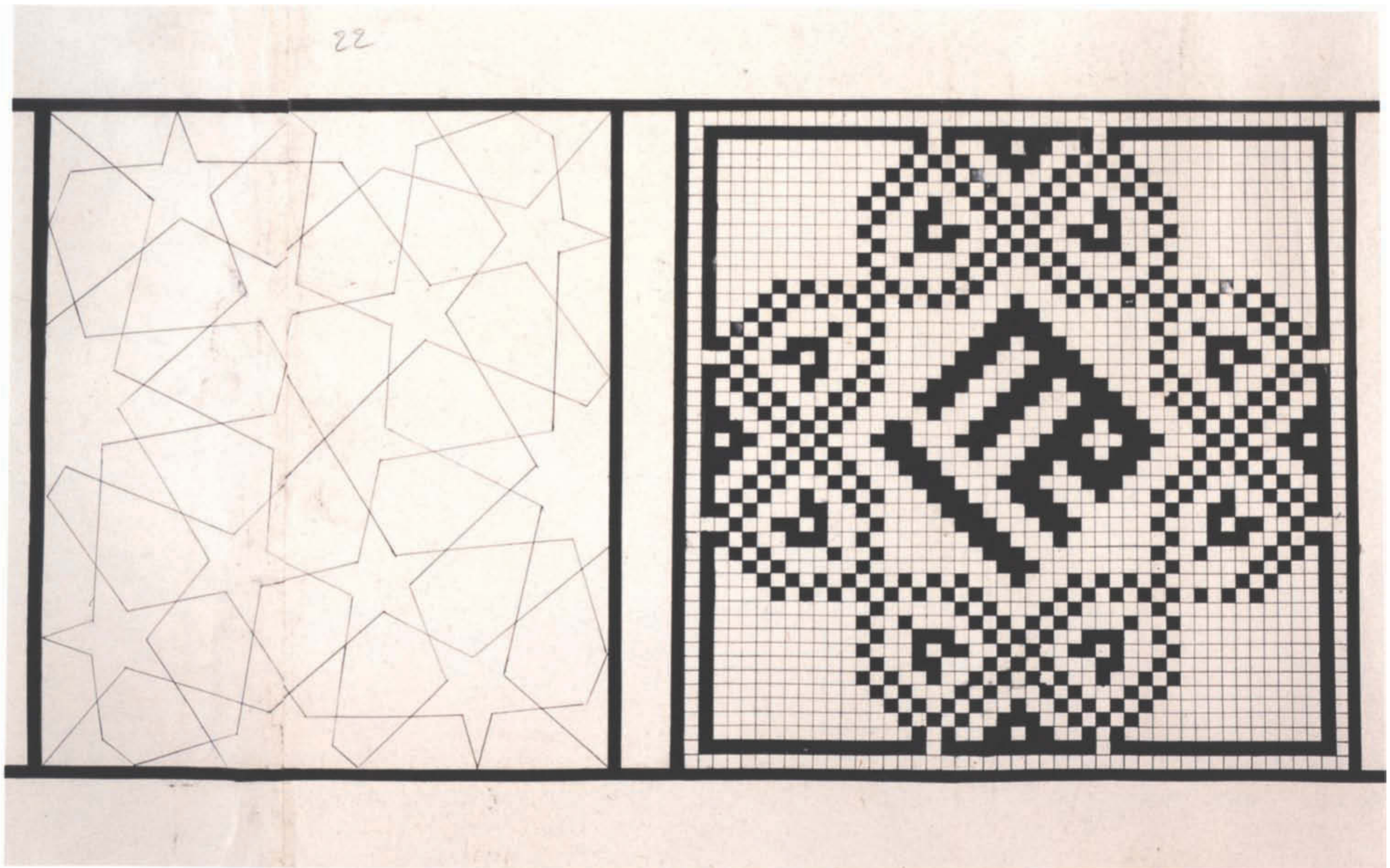

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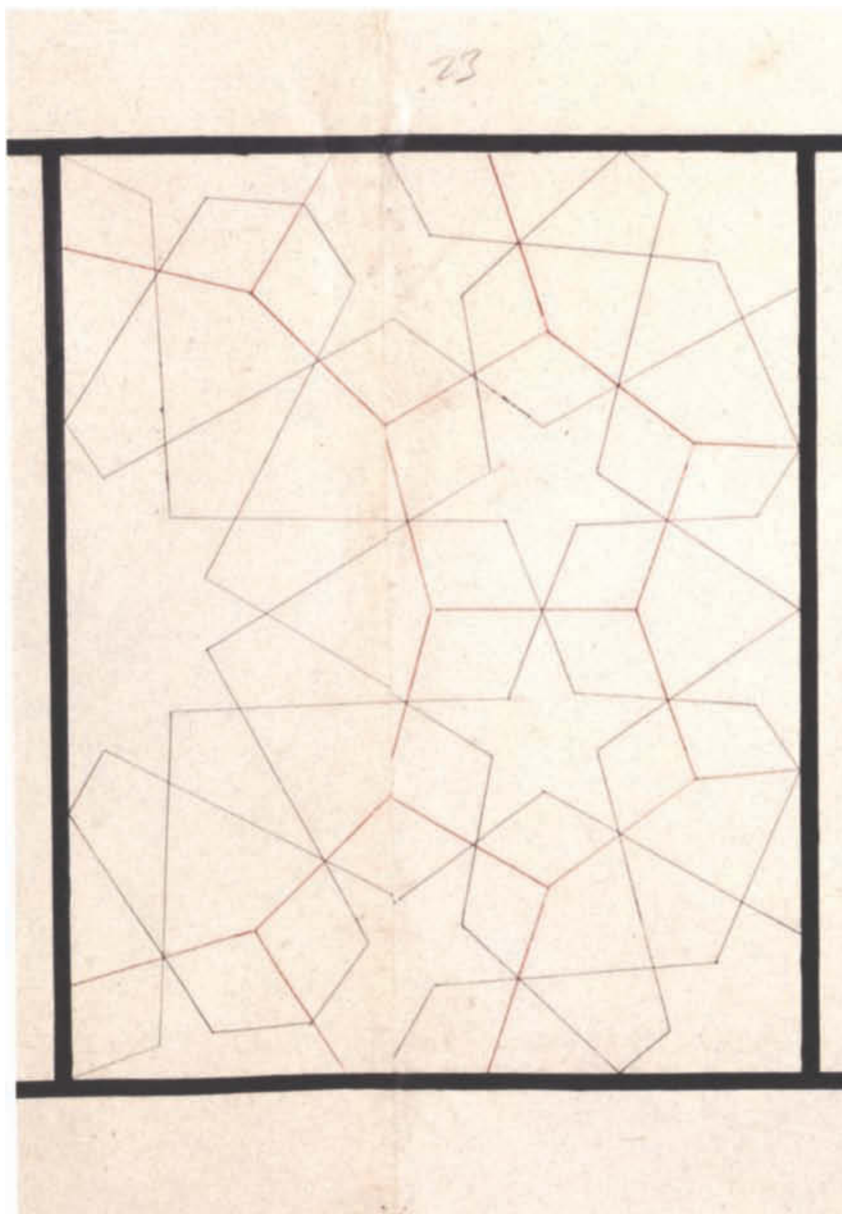

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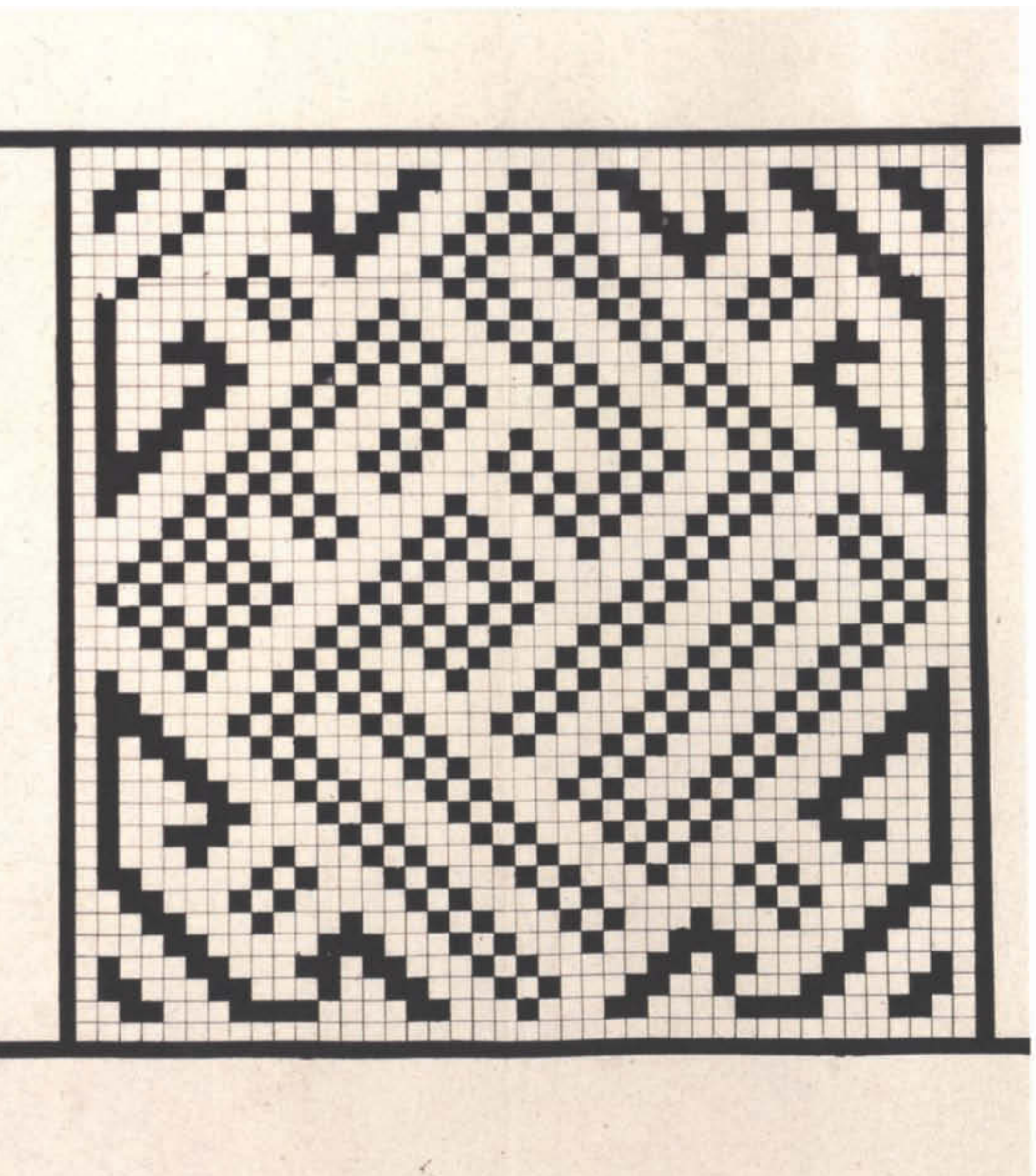

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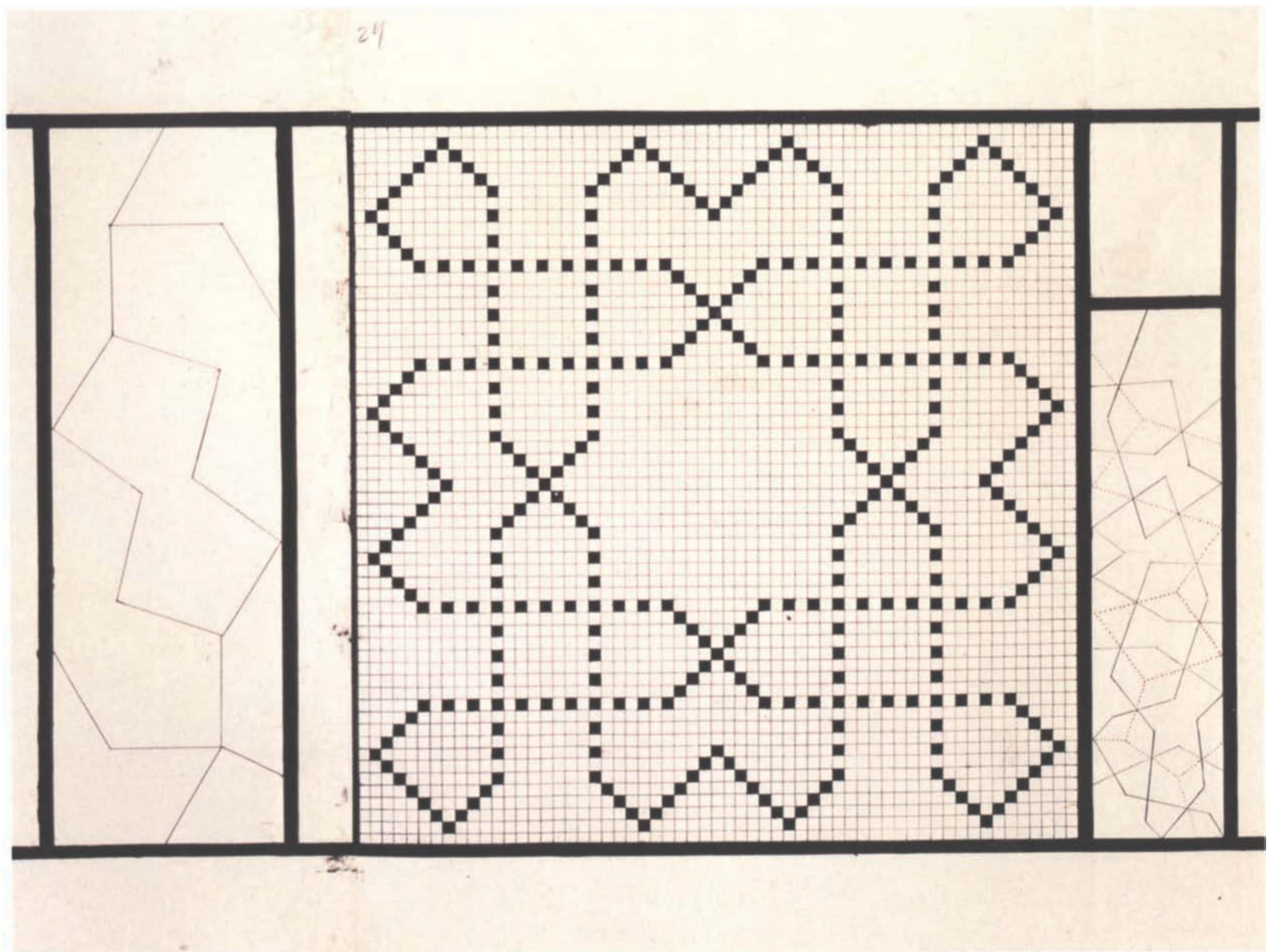

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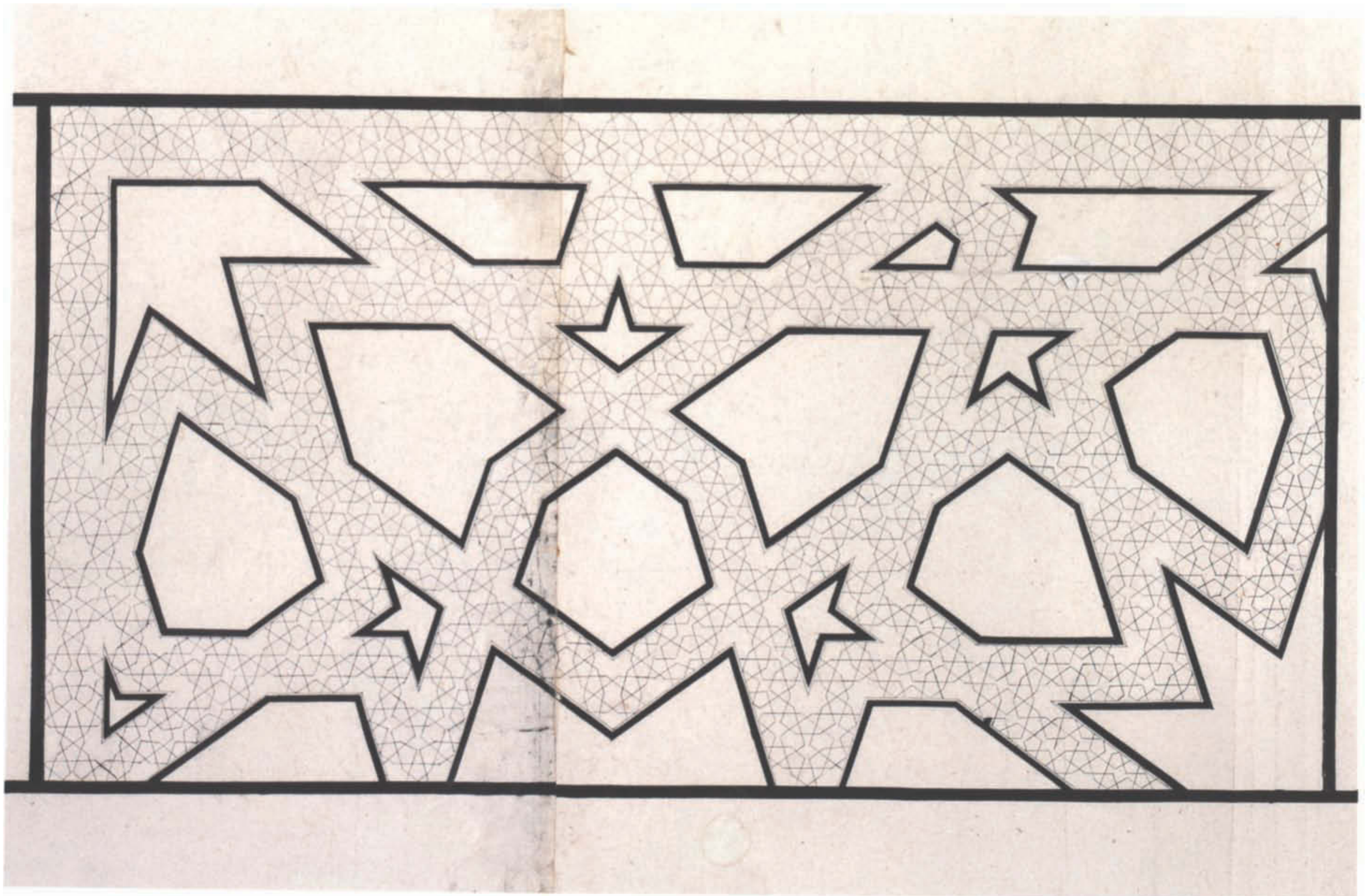

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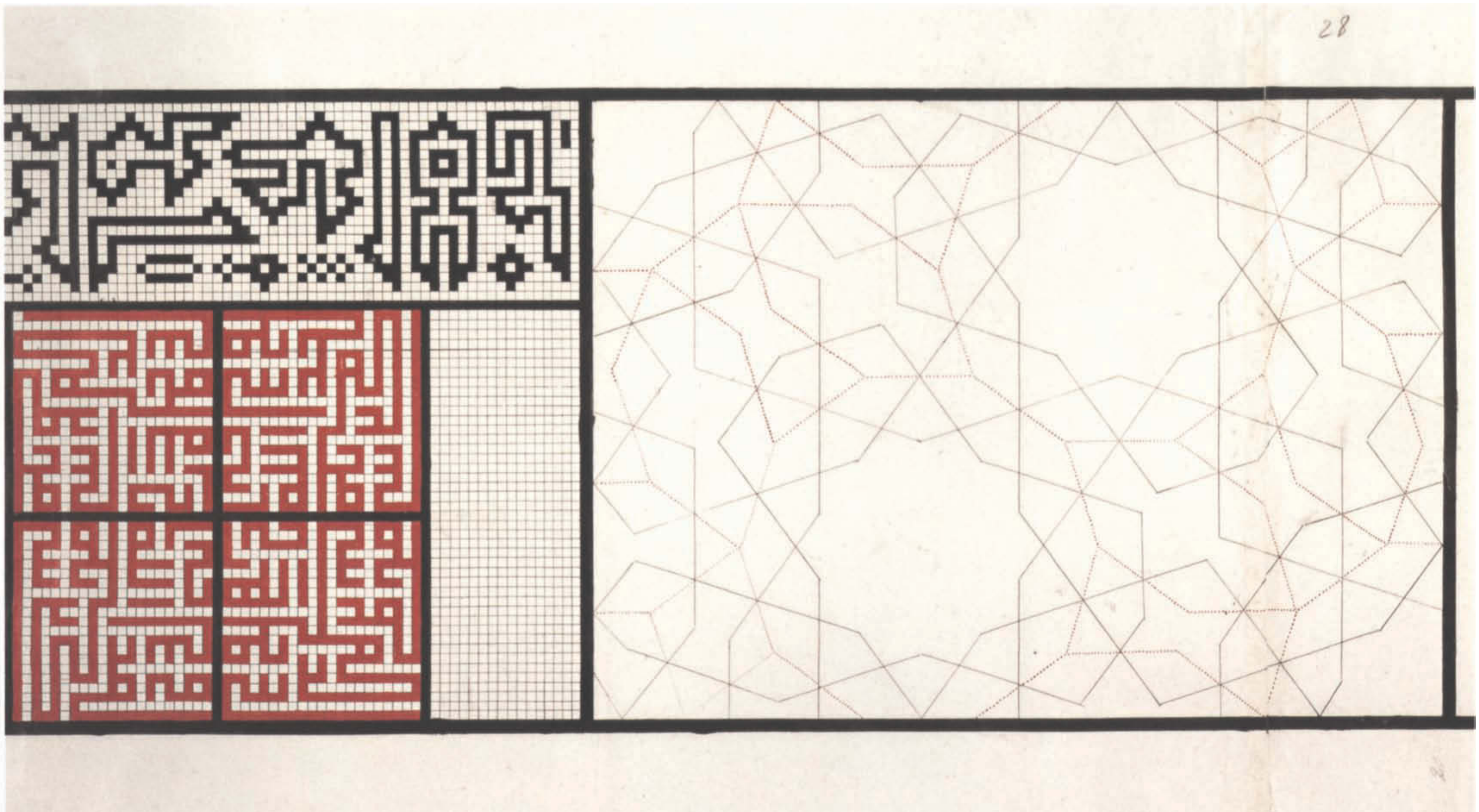

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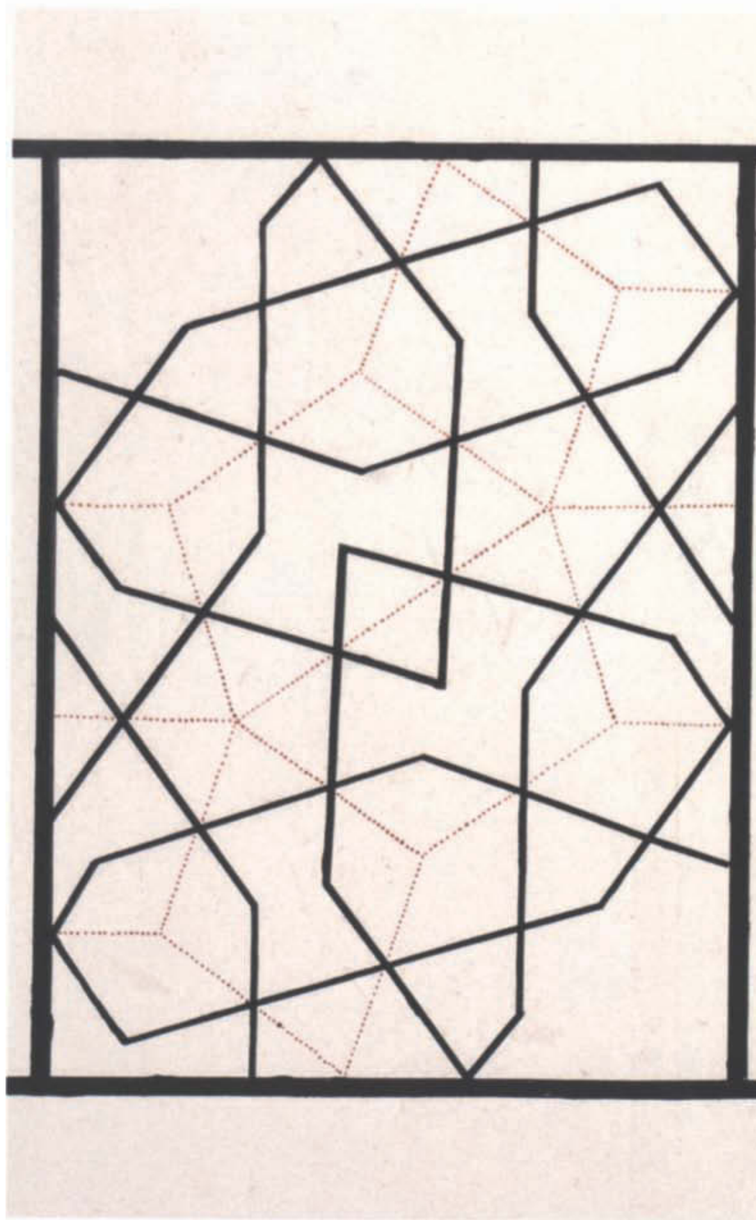

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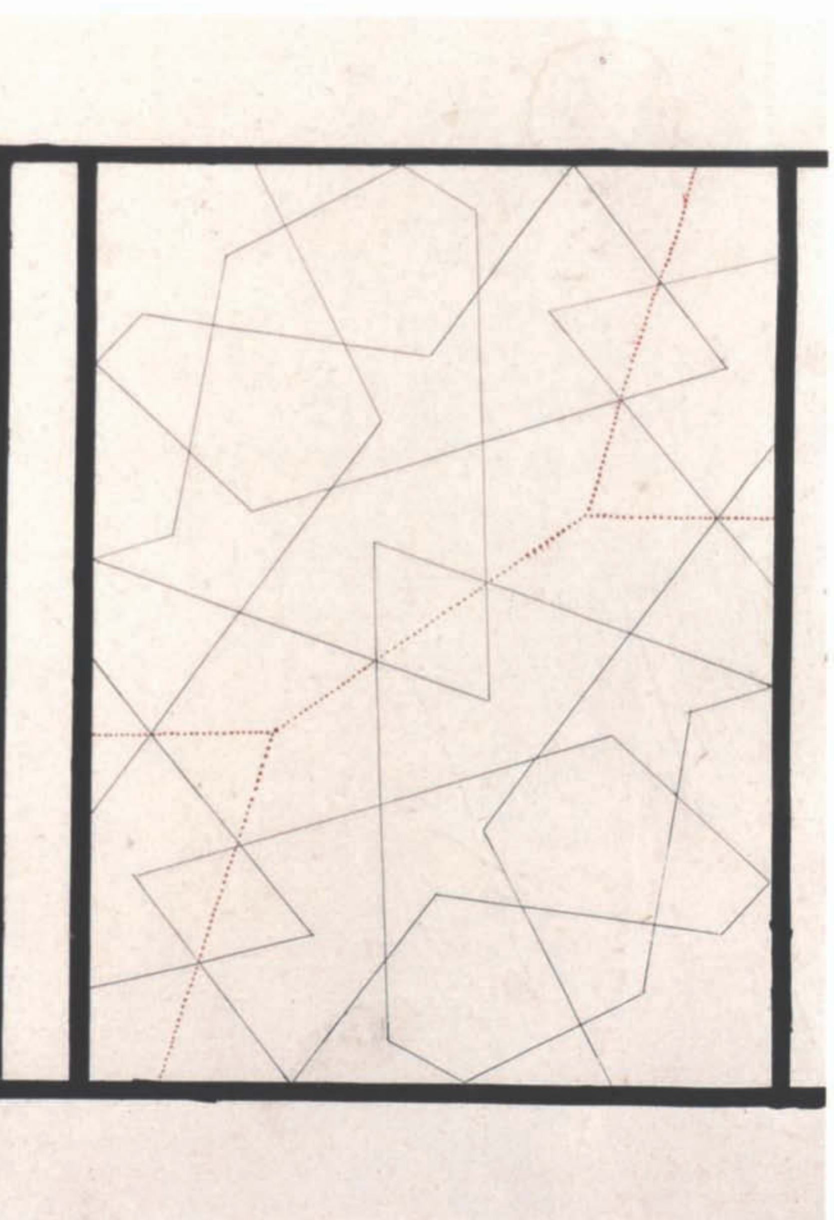

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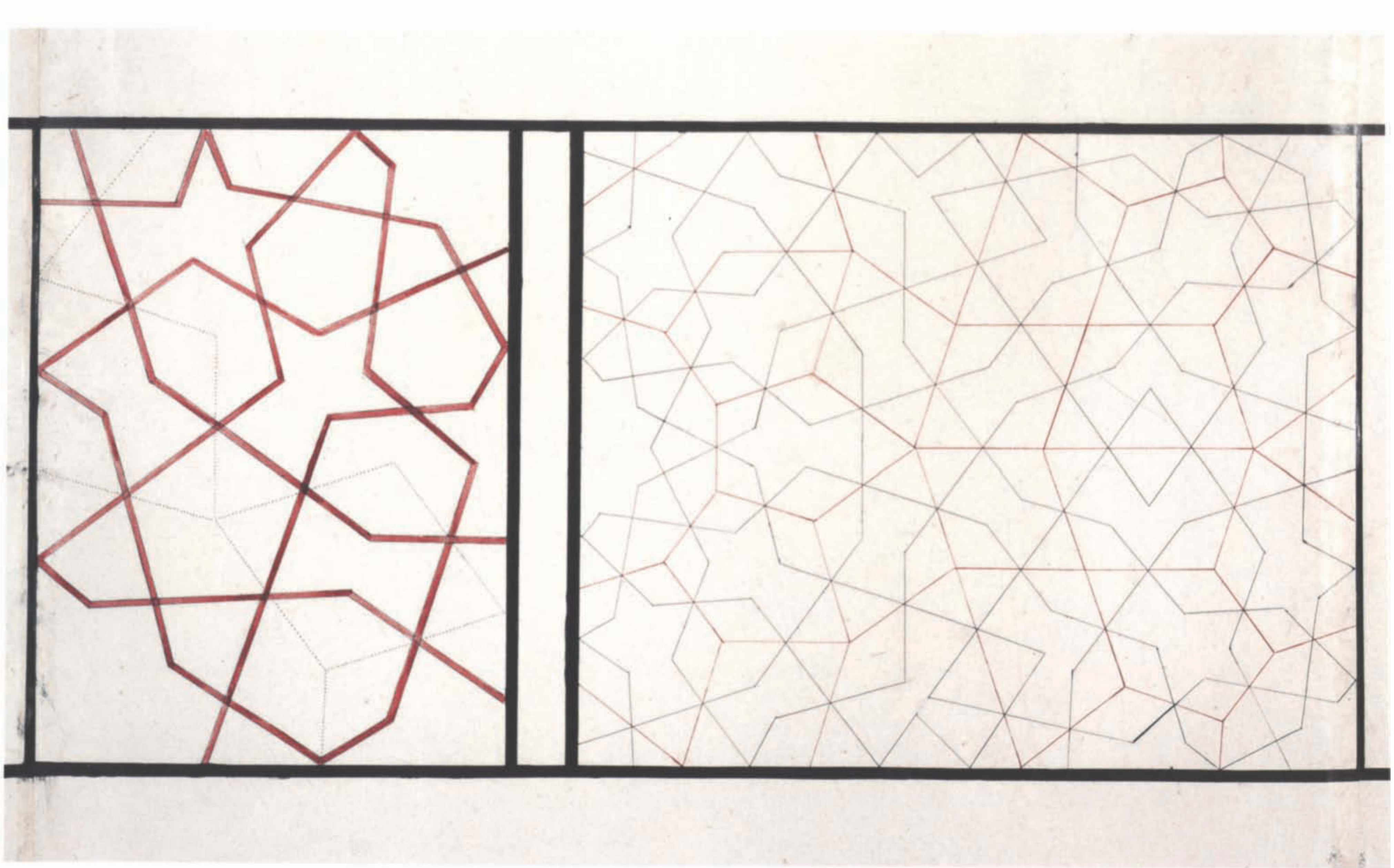

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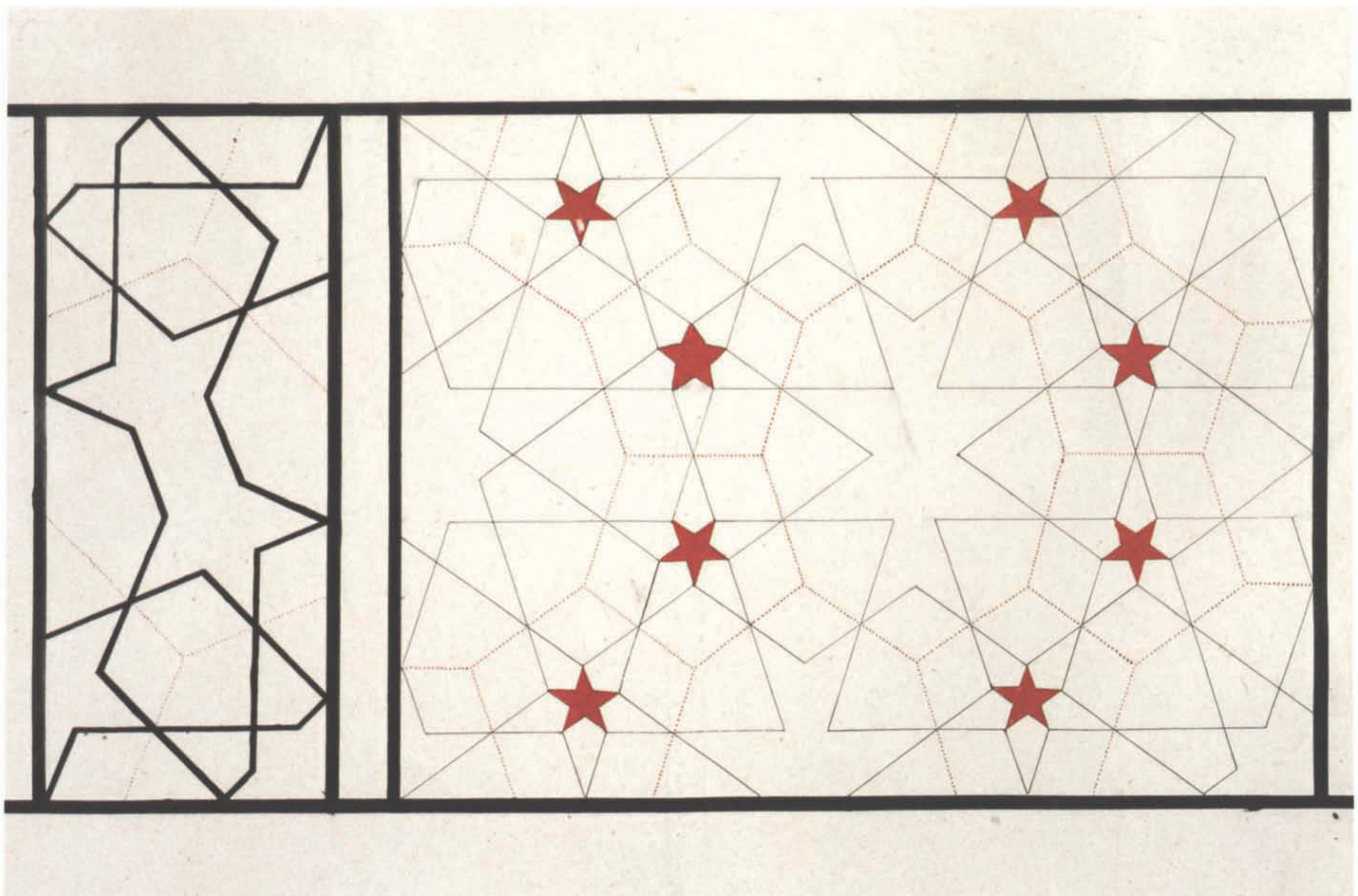

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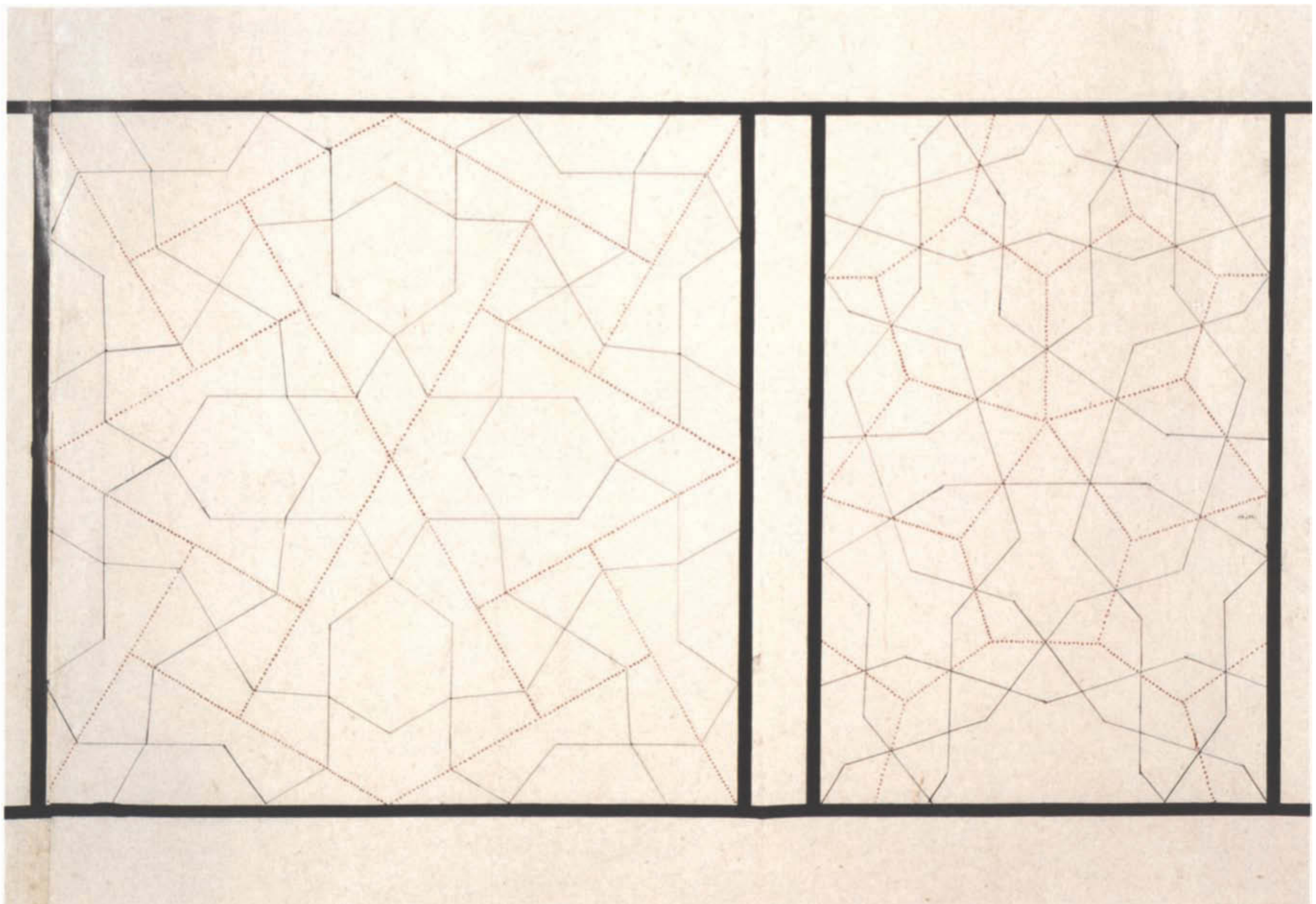

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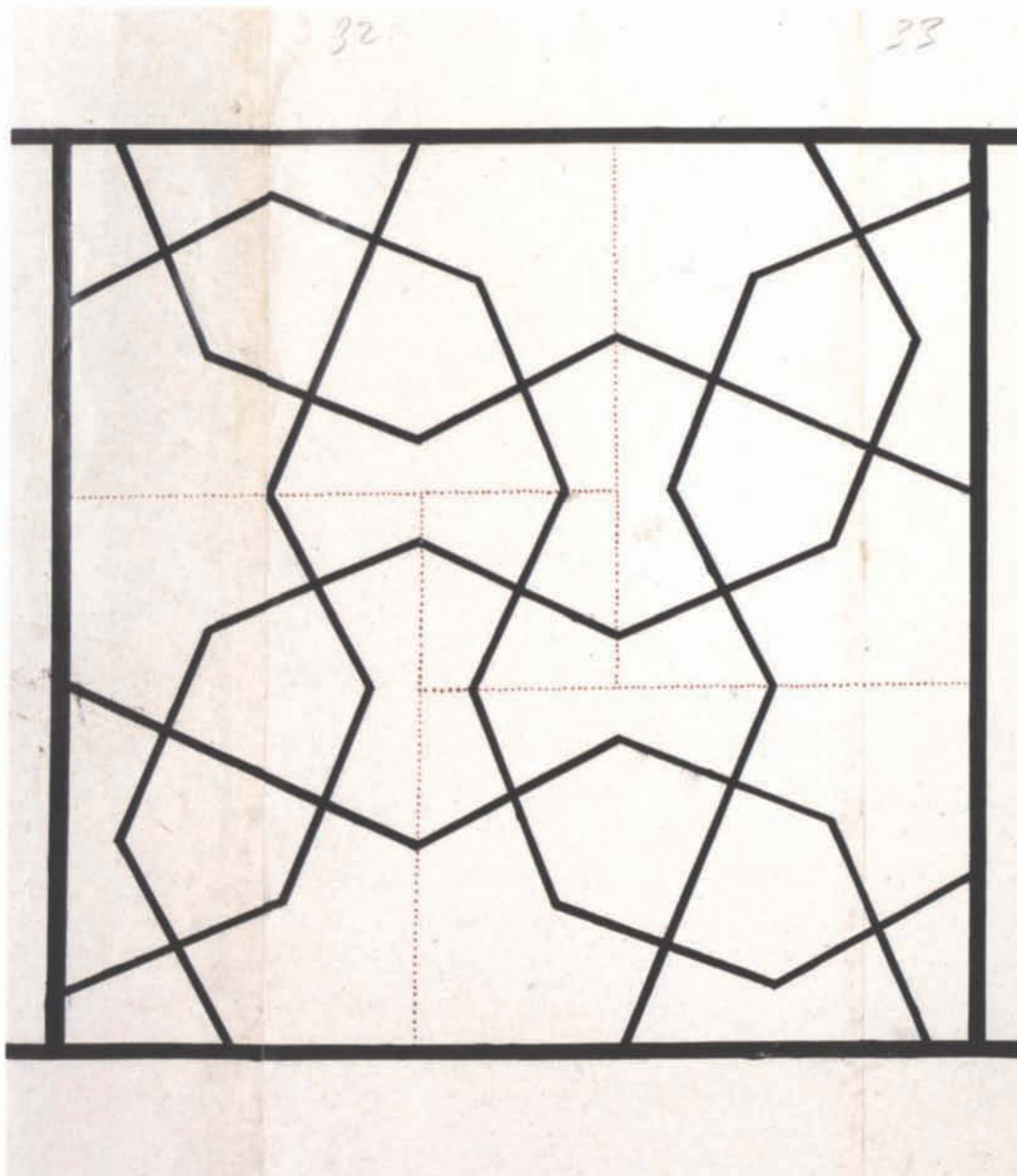

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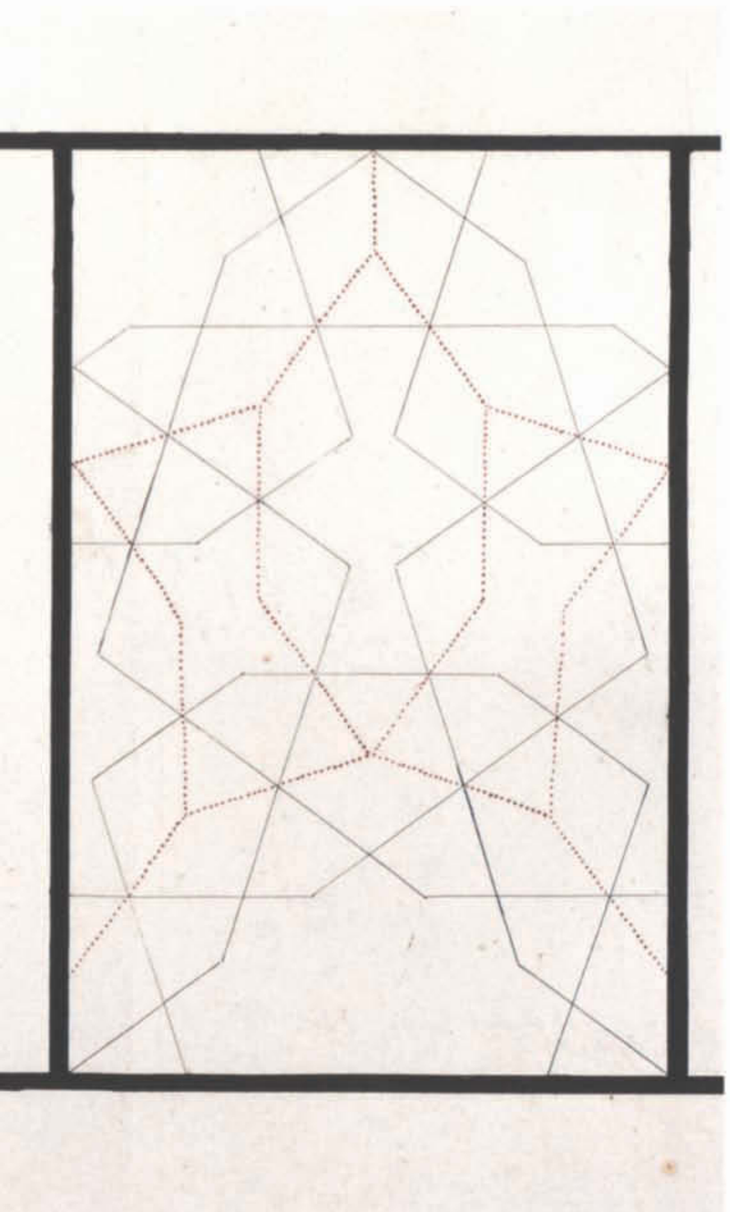

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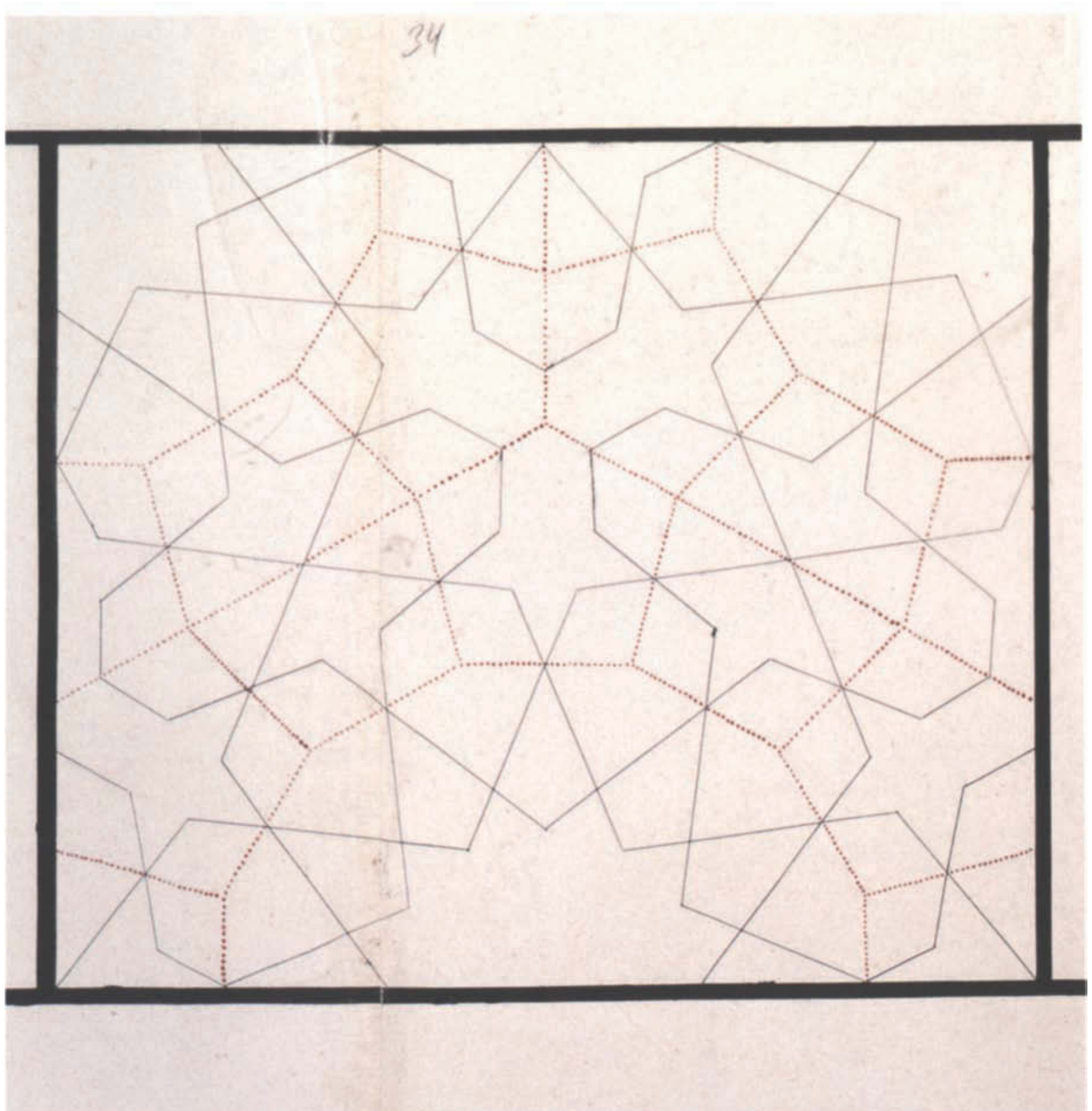

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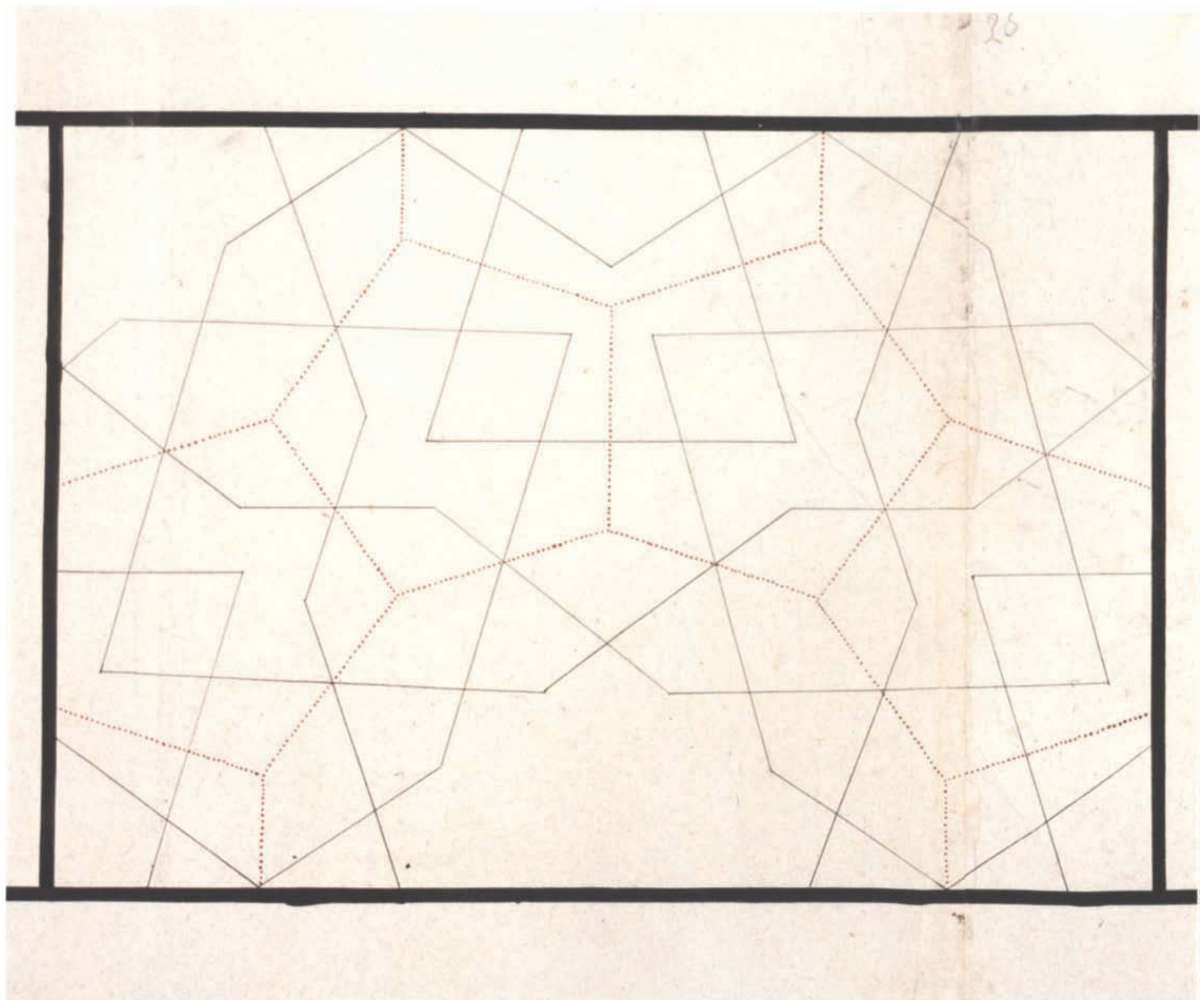

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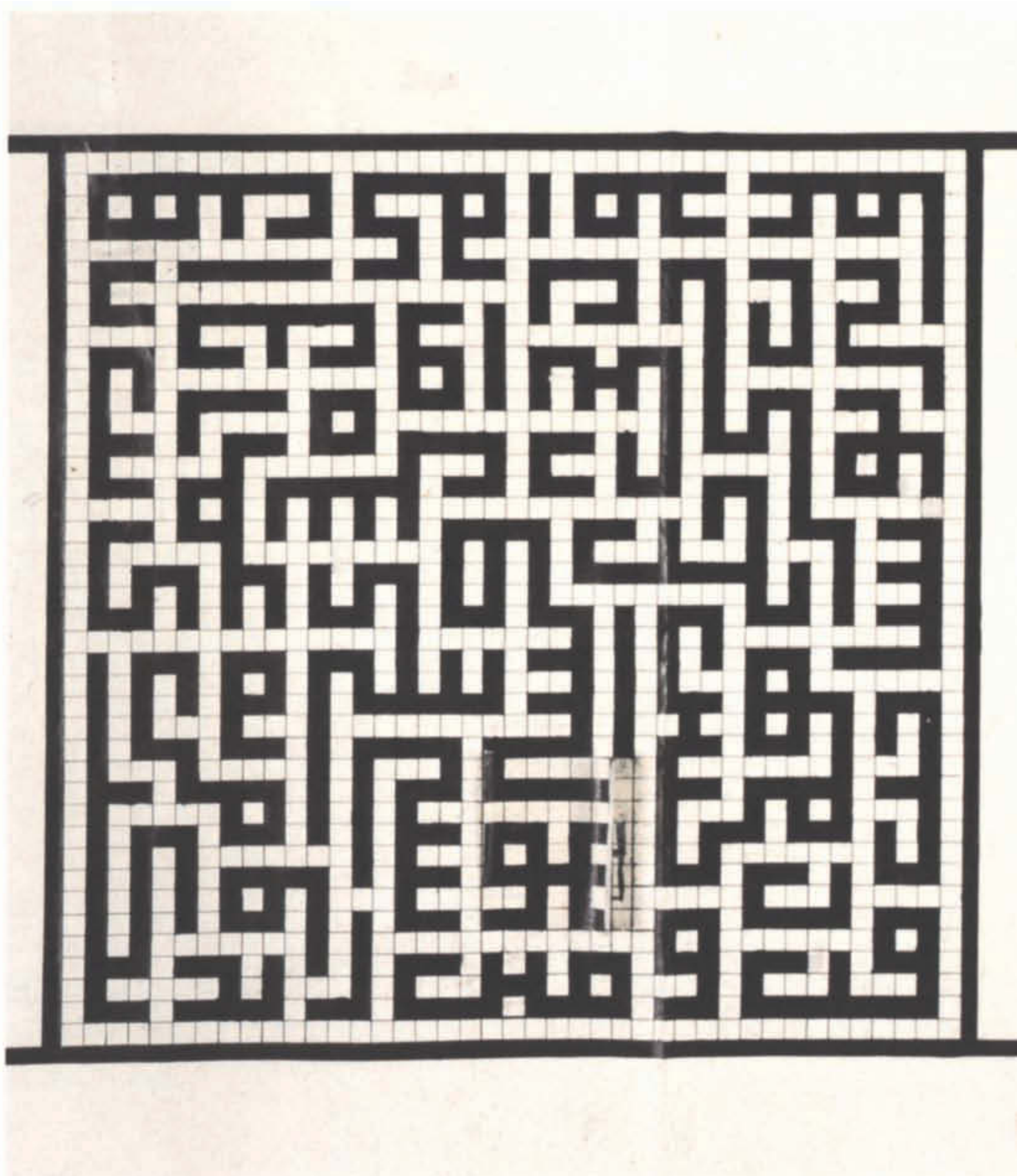

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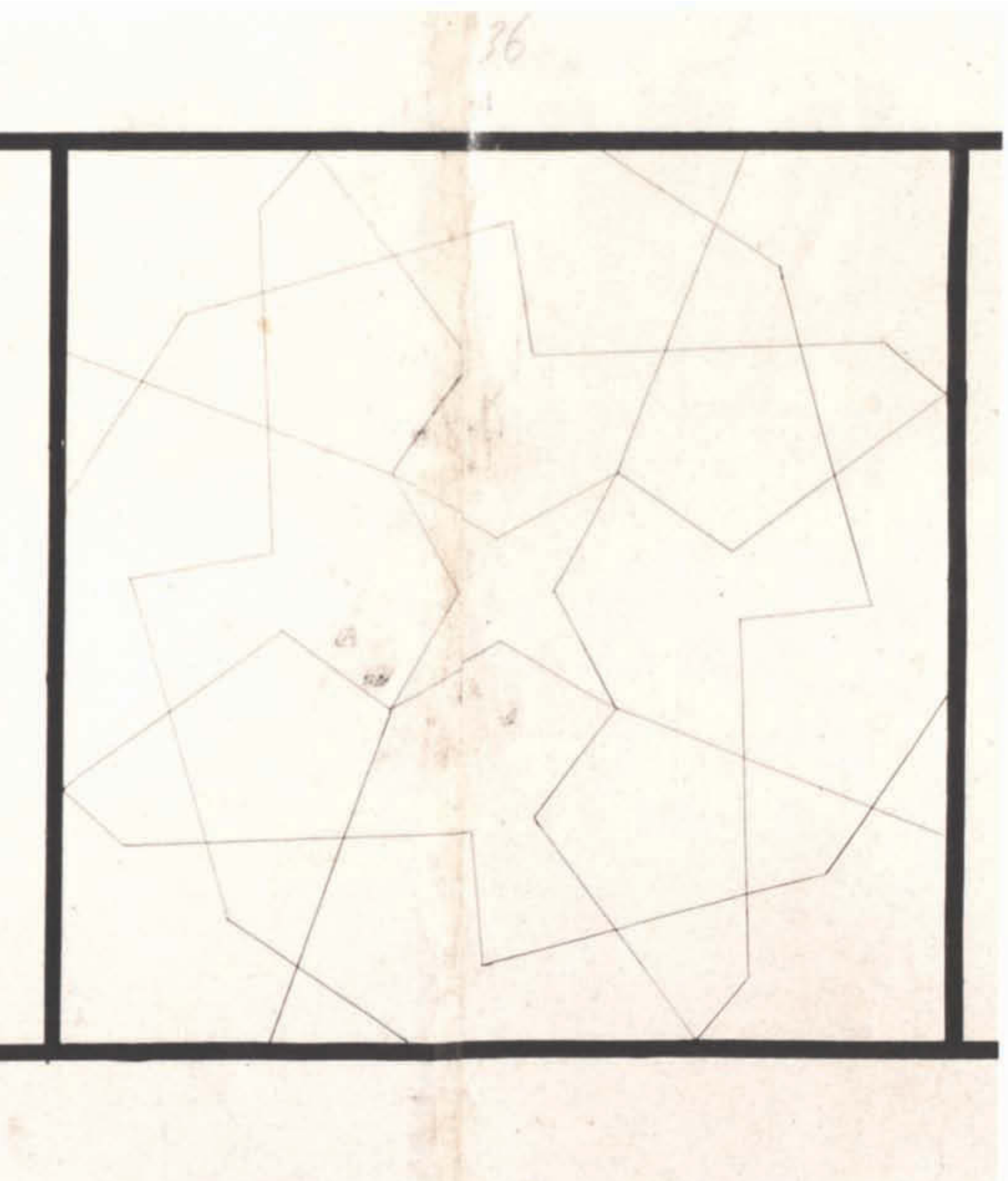

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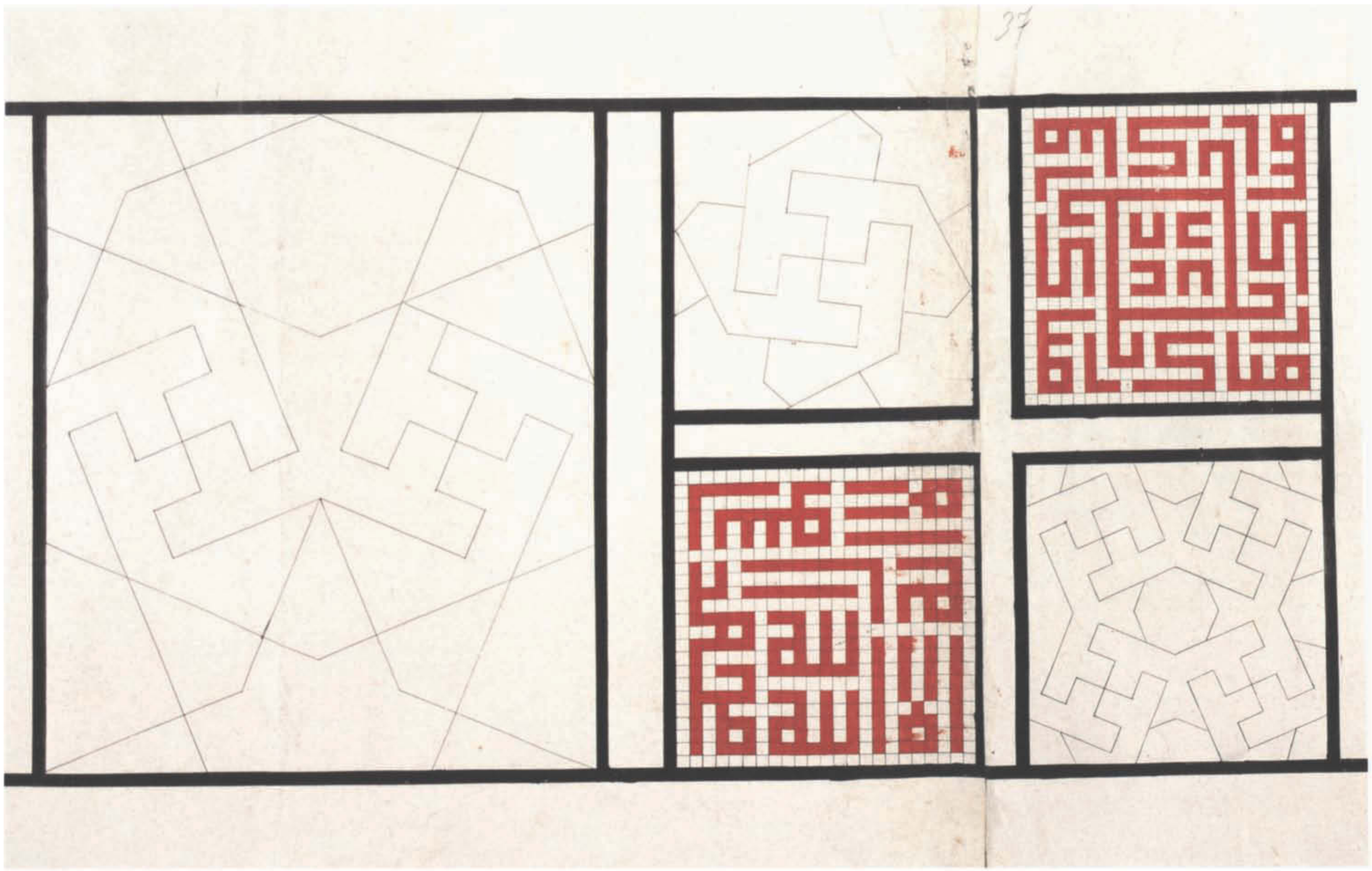

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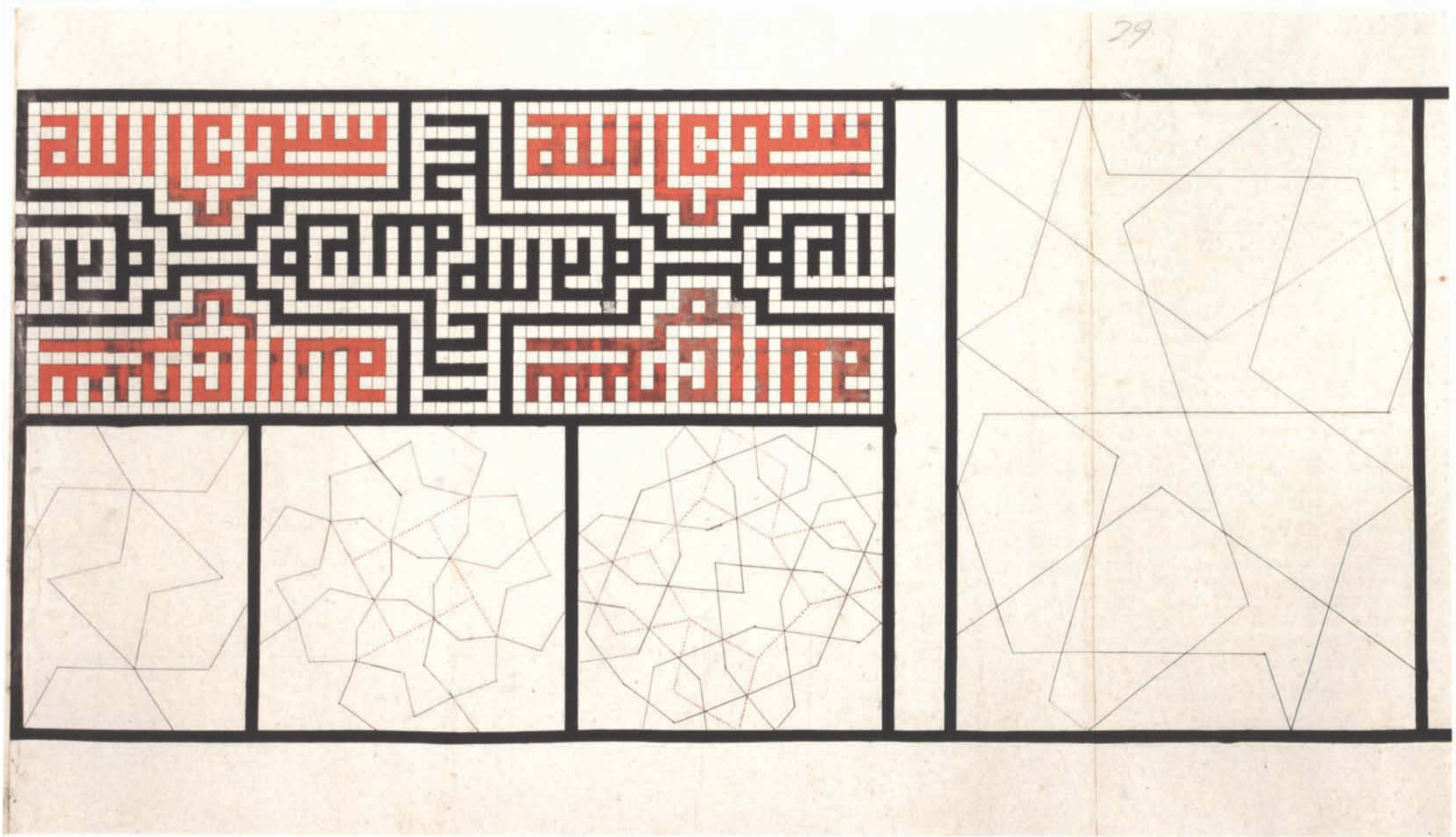

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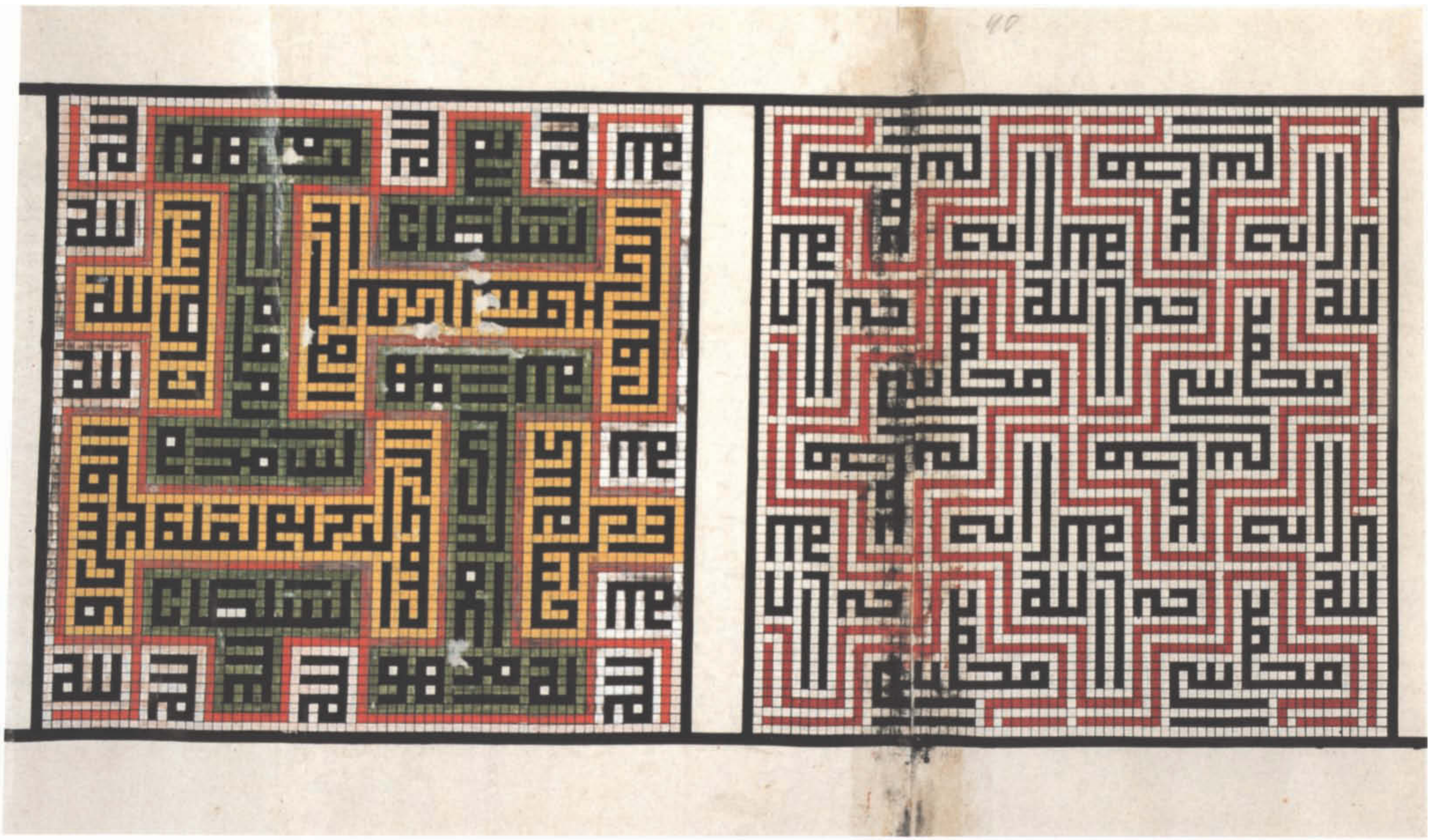

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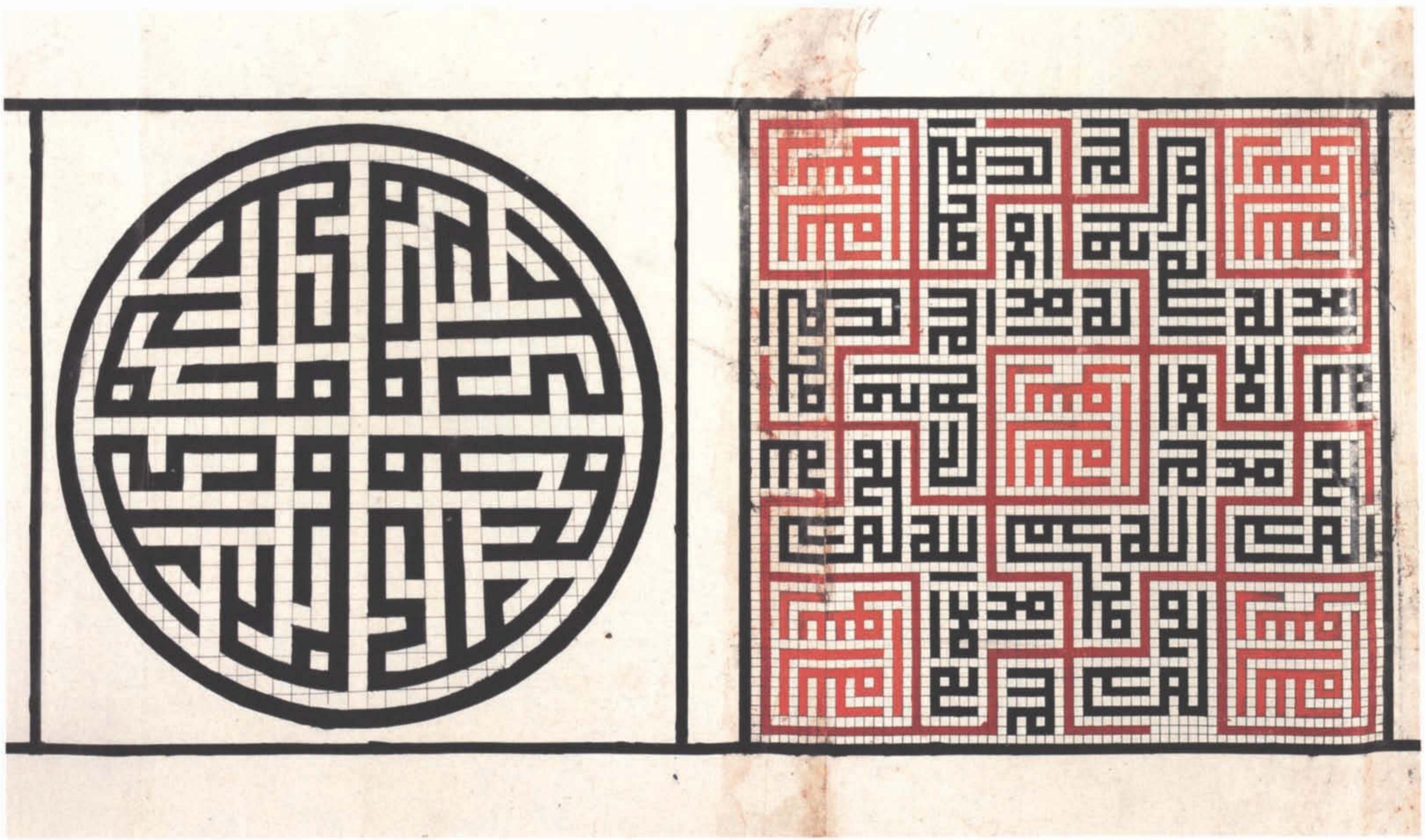

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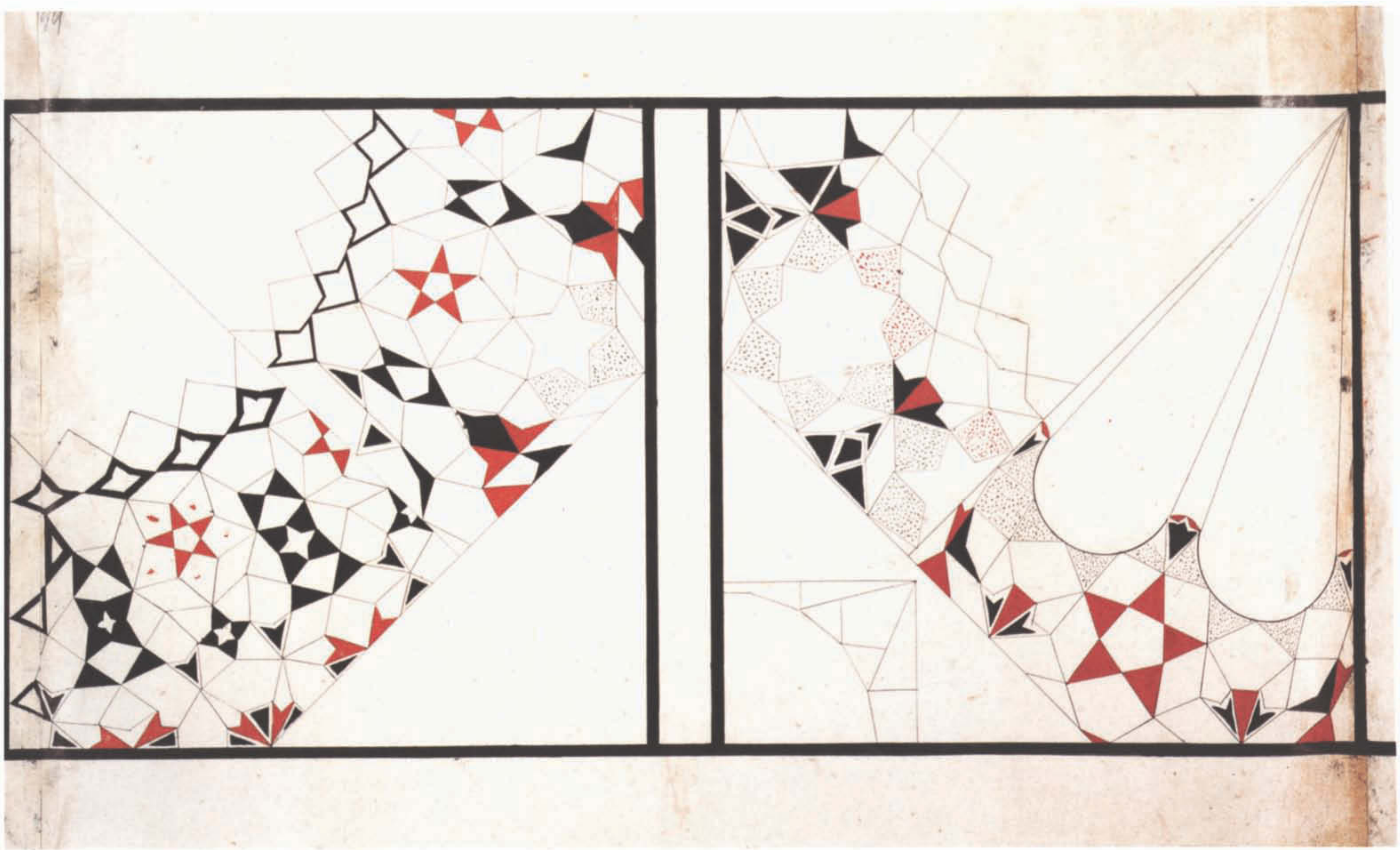

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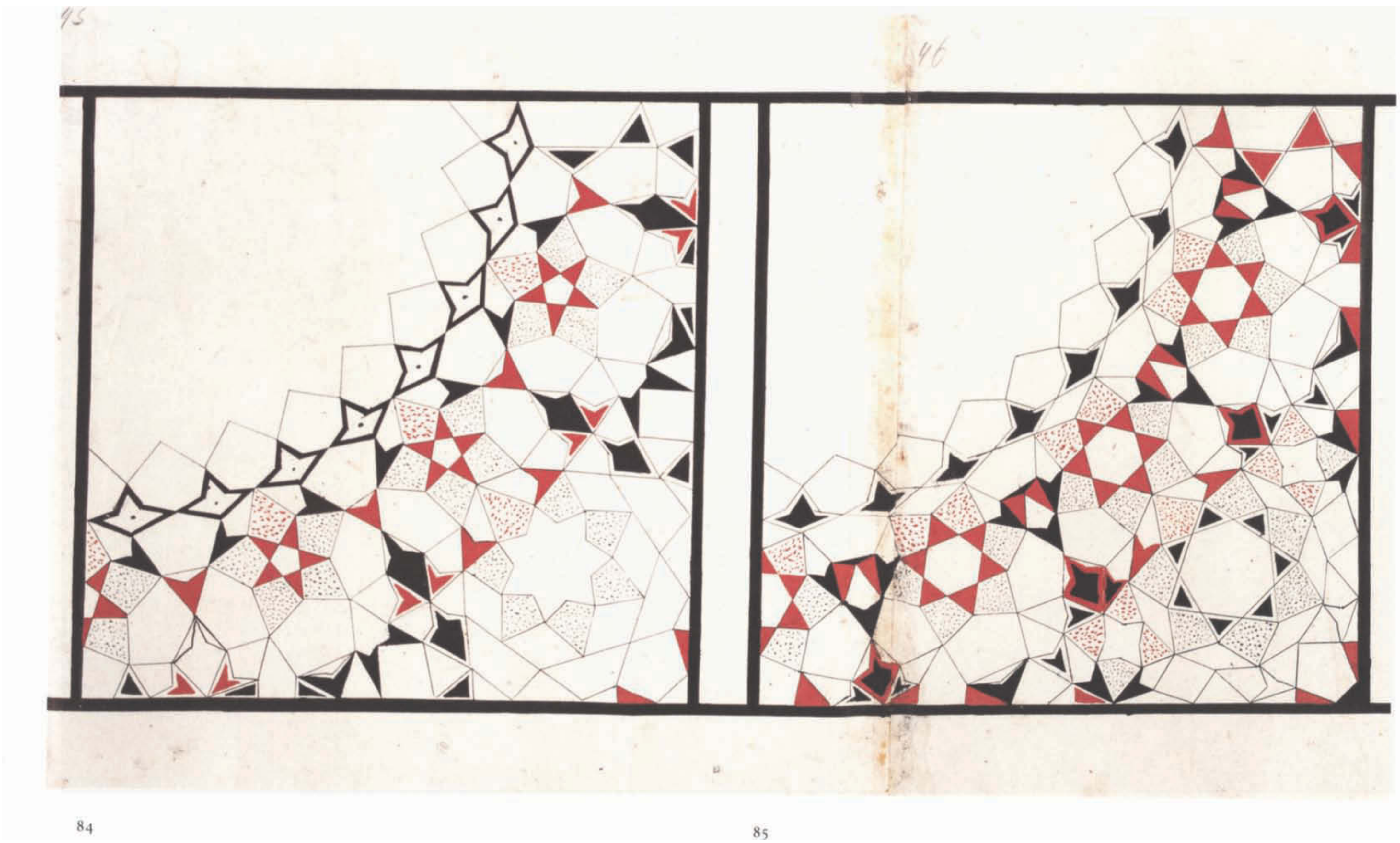

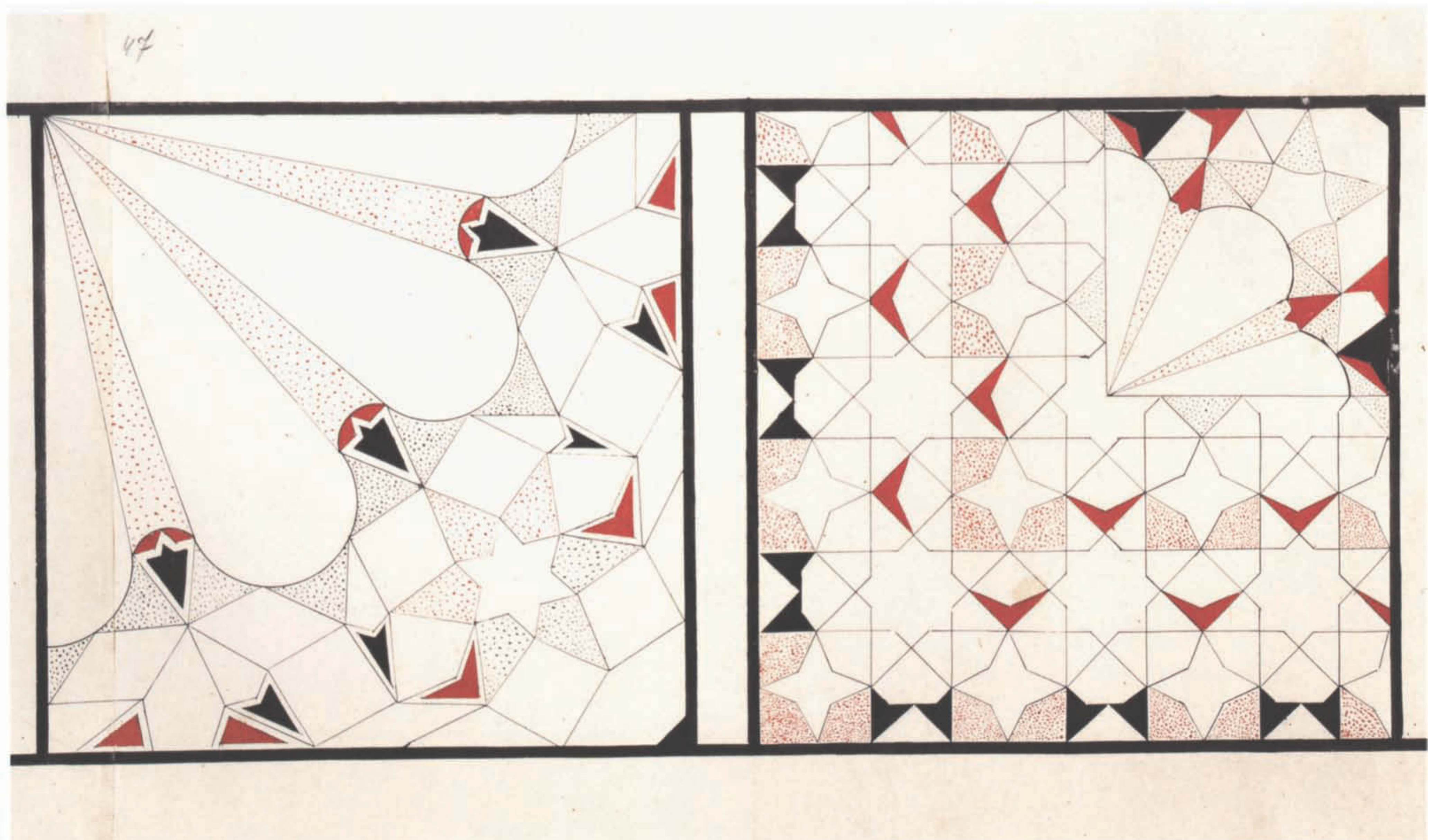

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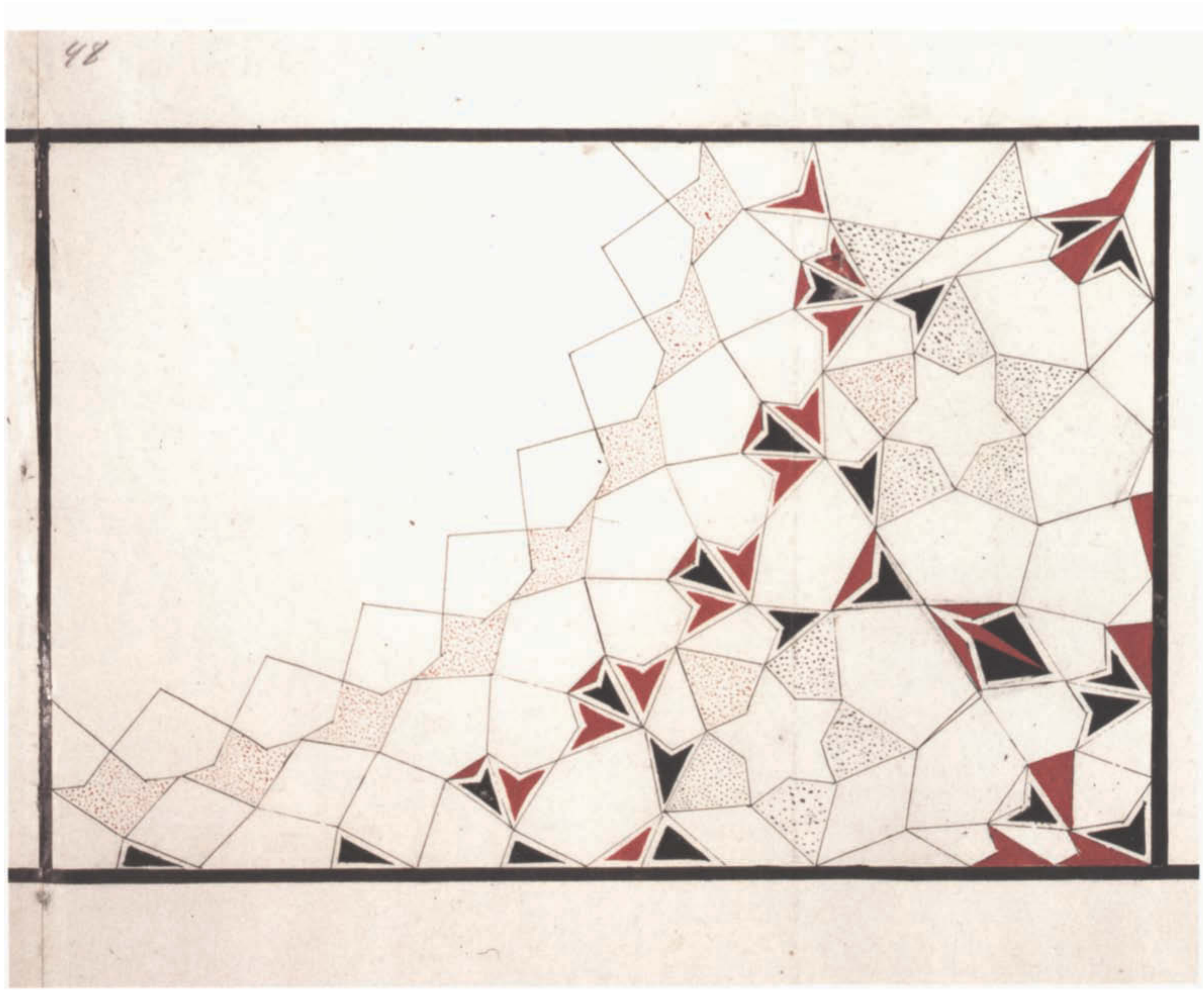

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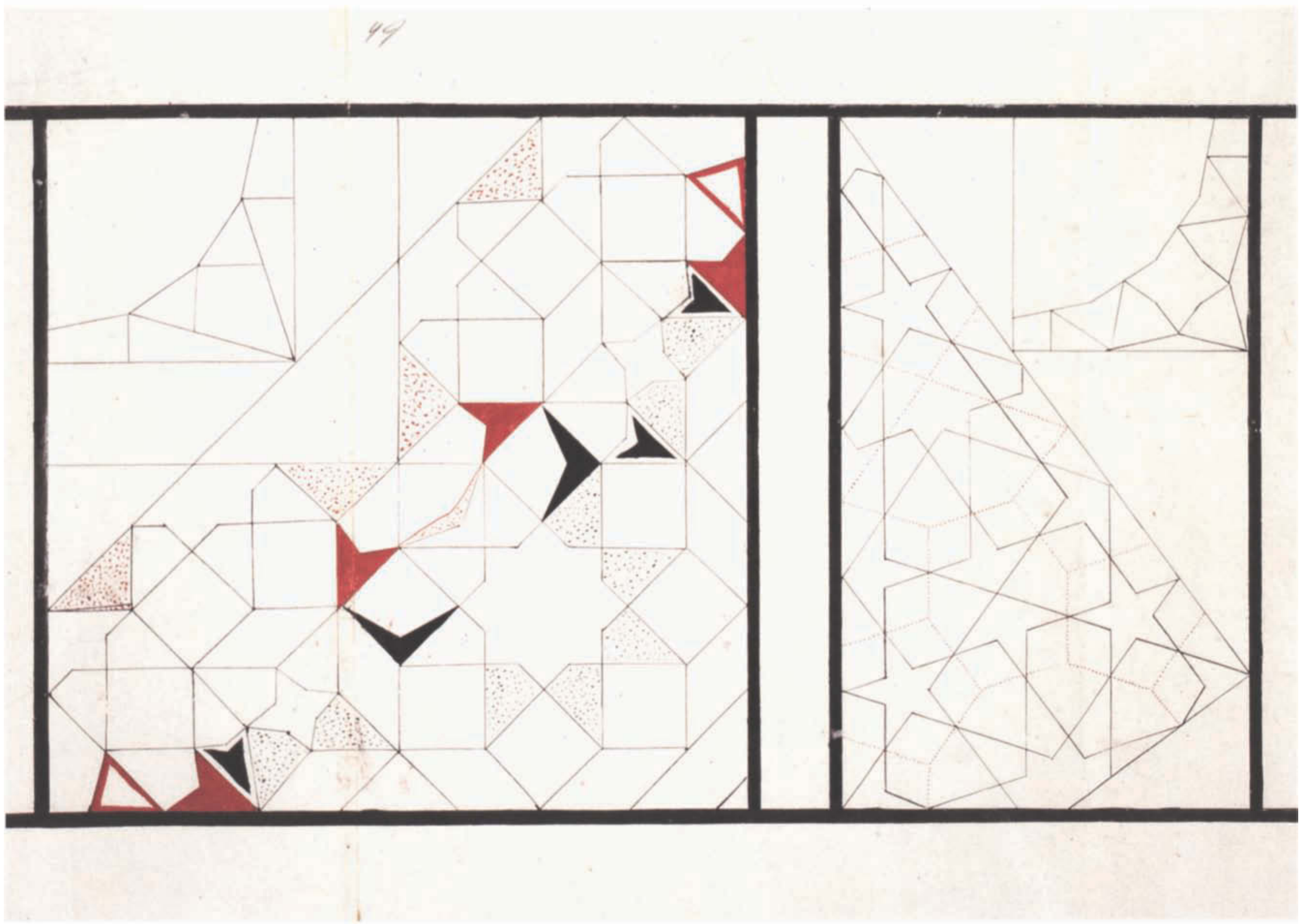

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92 a b

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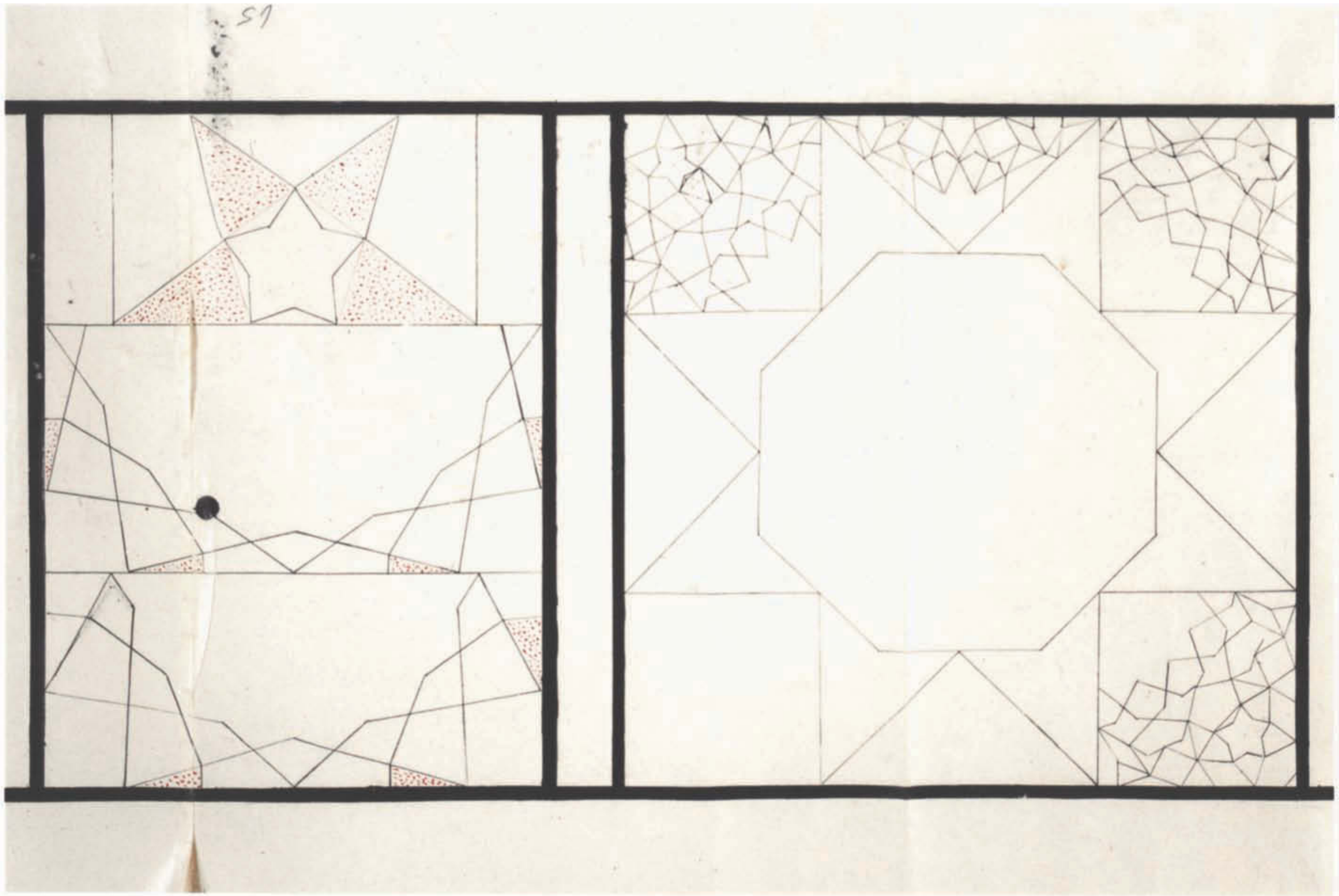

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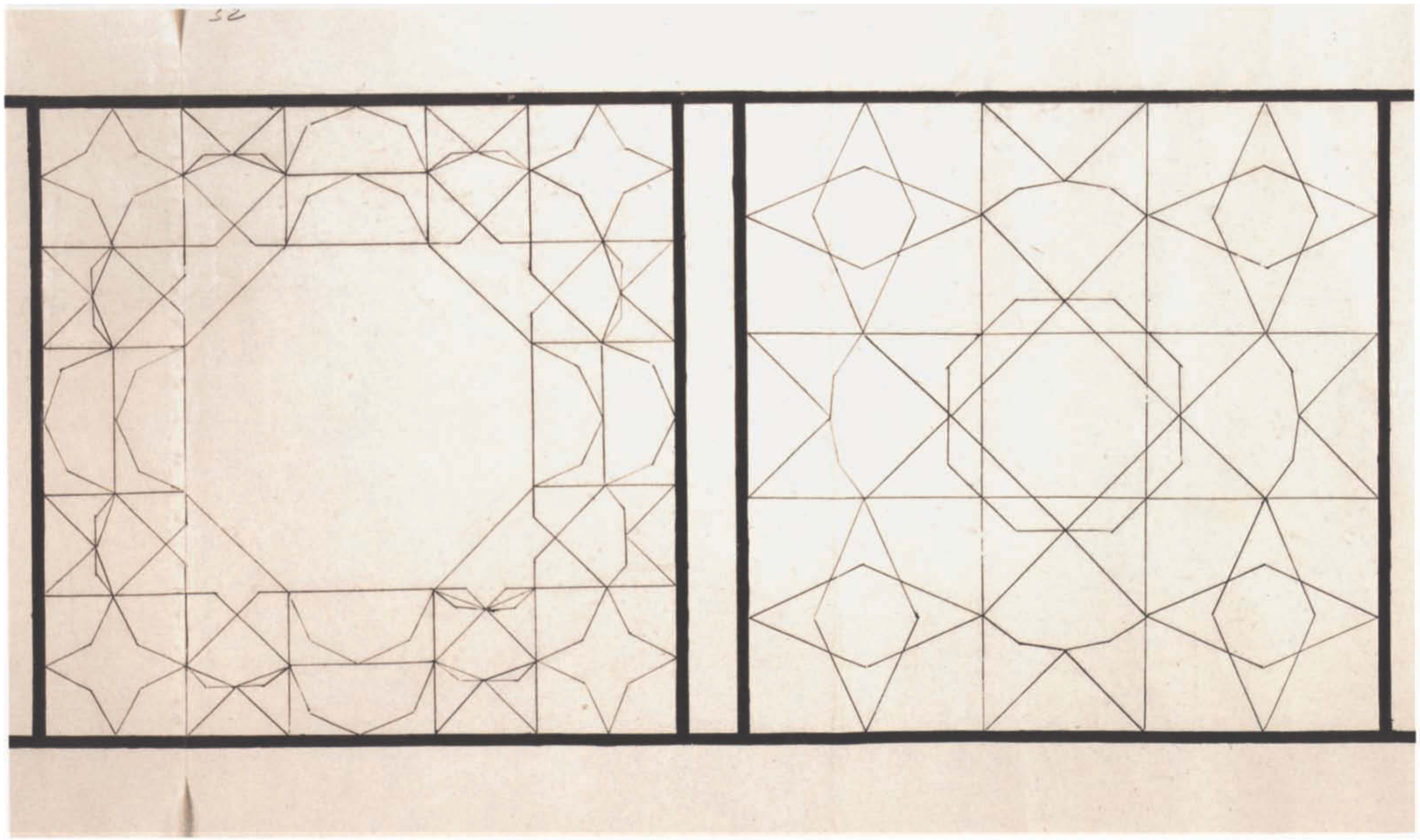

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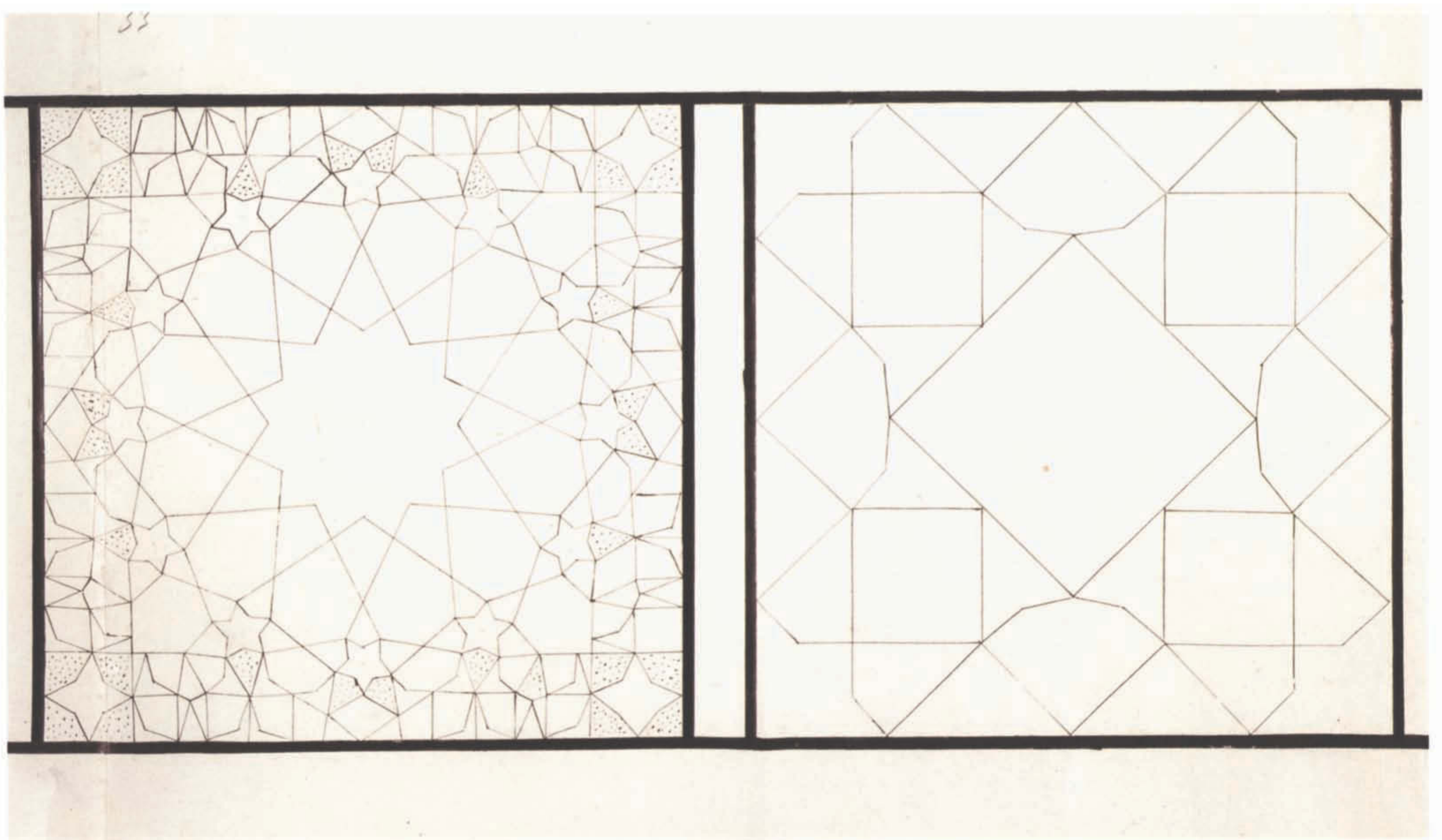

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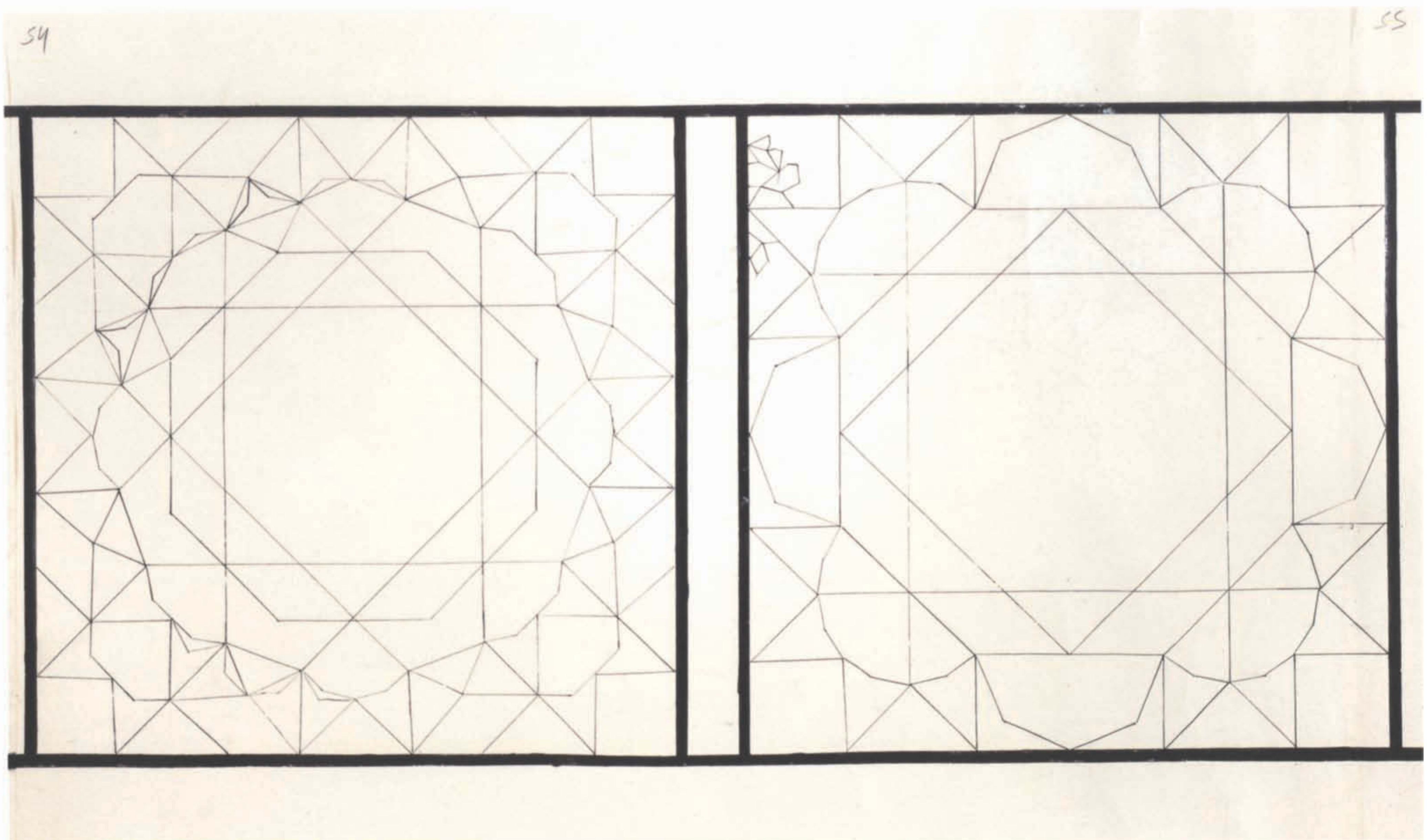

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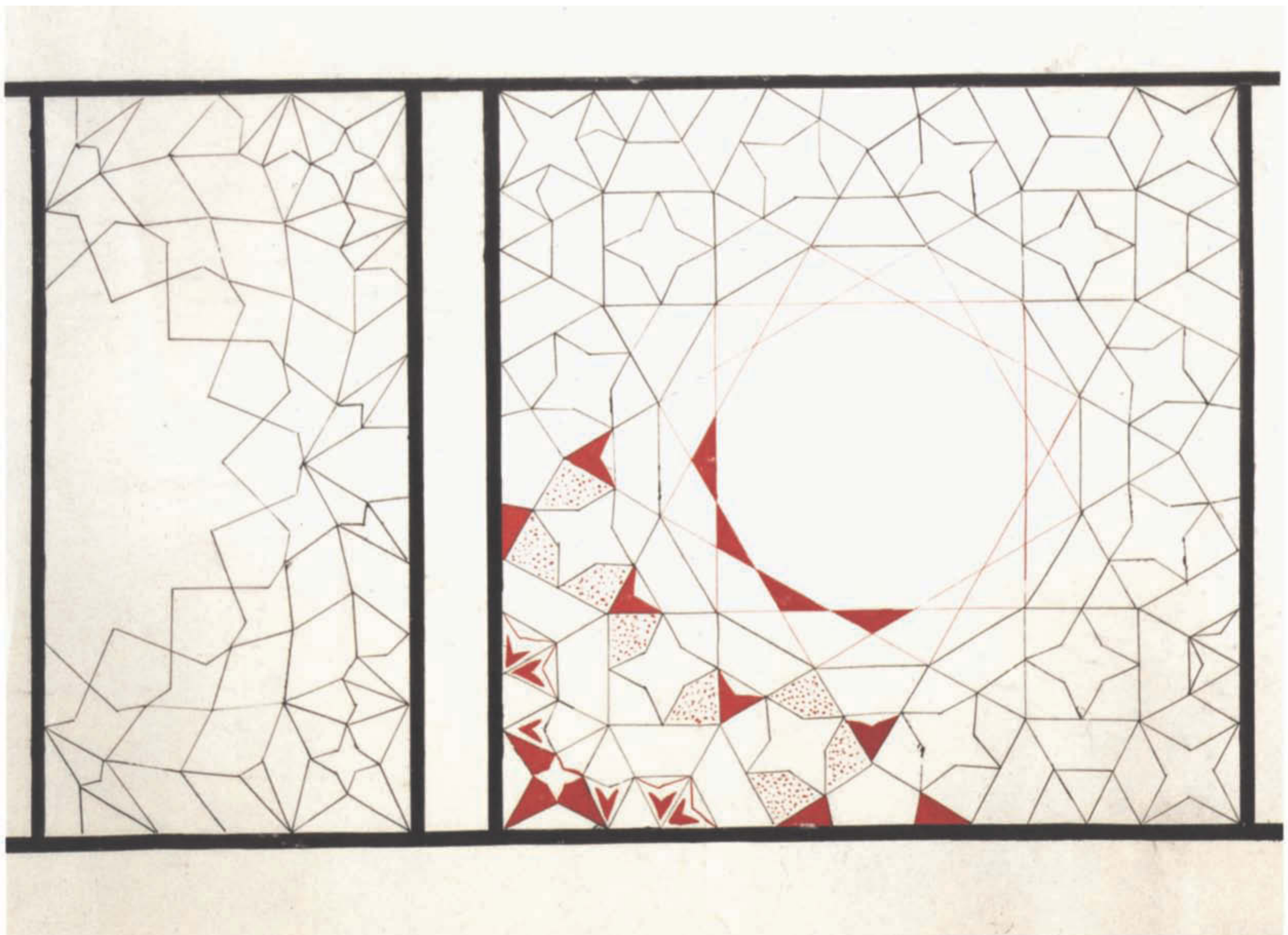

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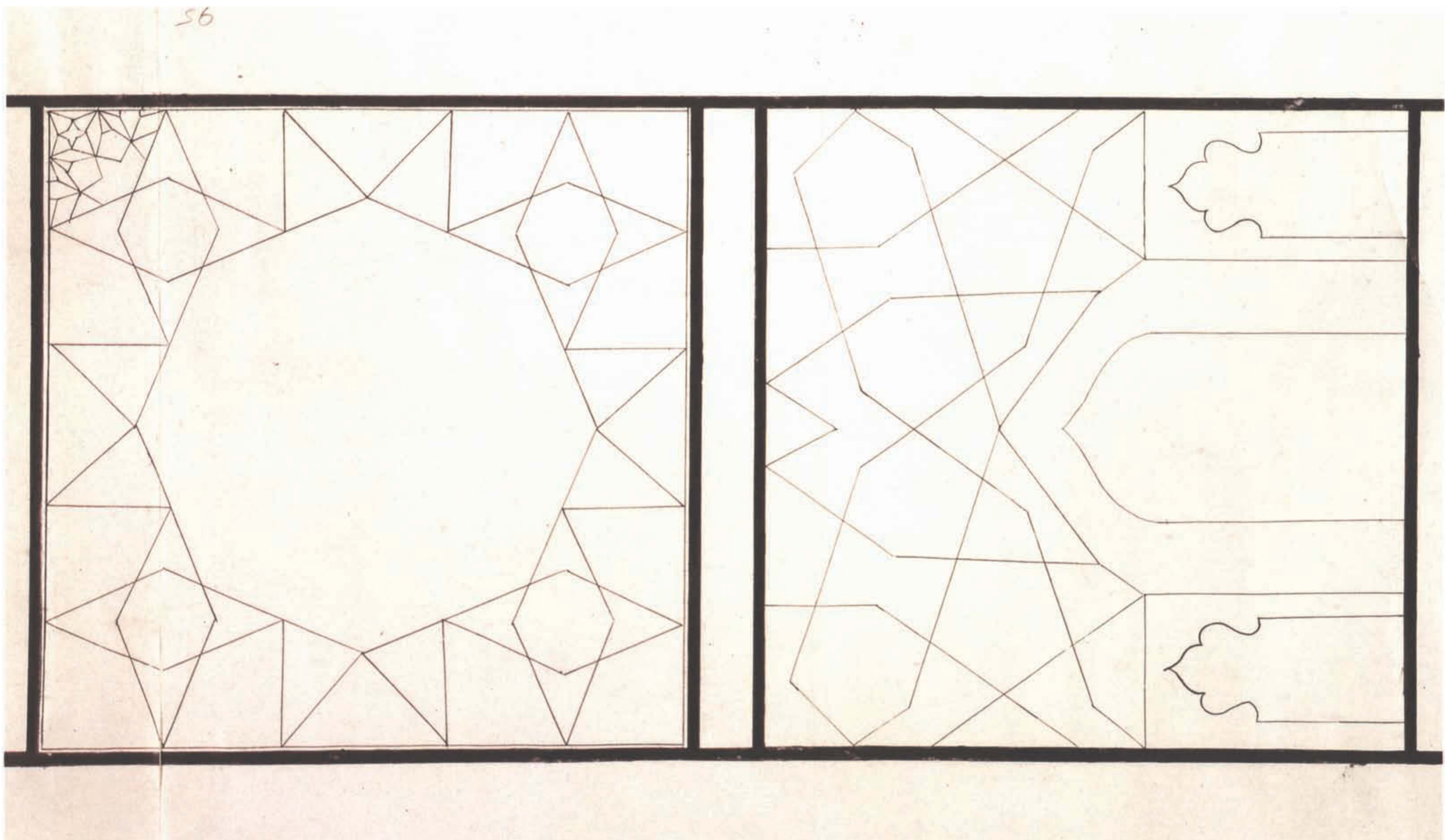

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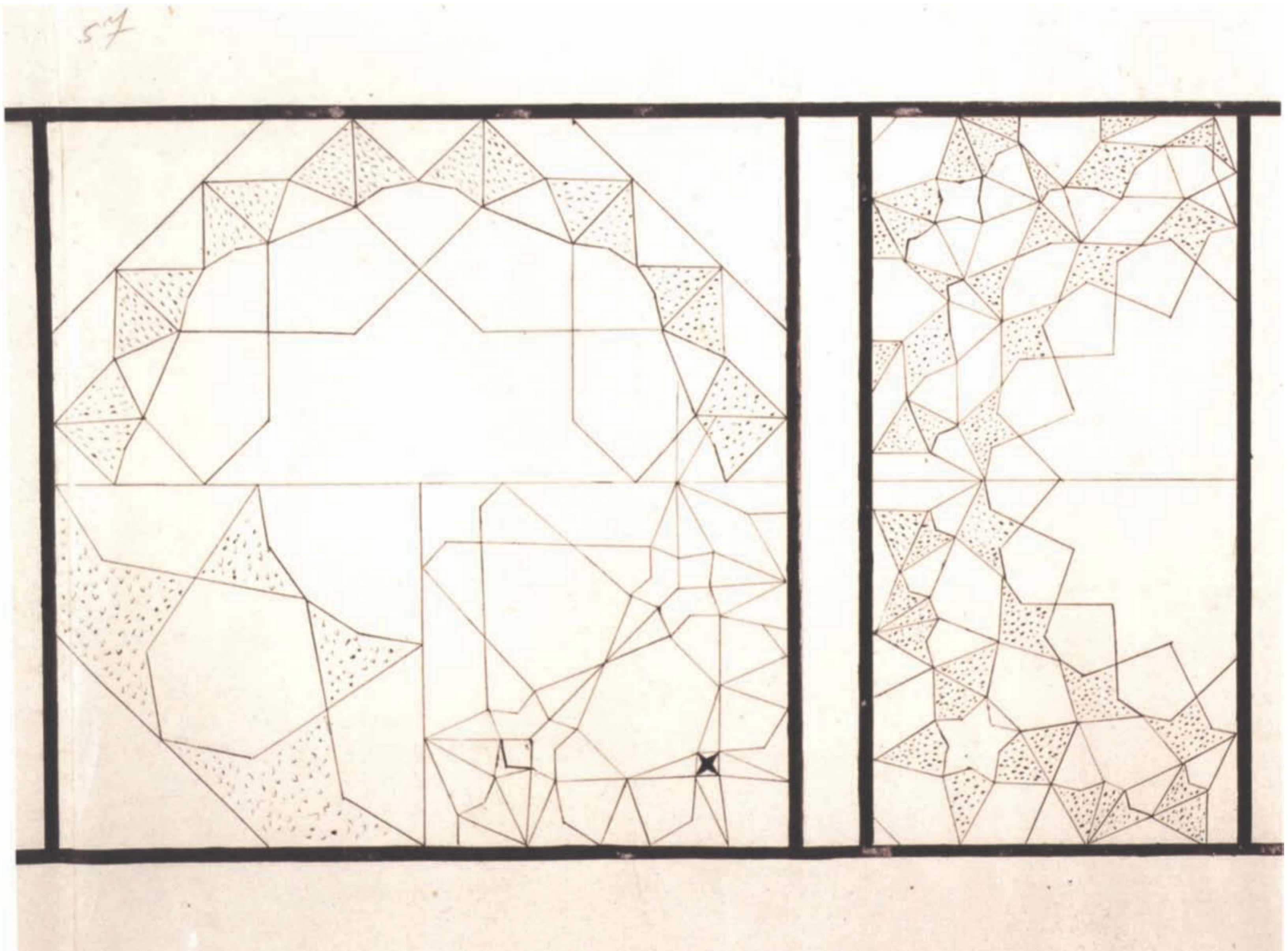
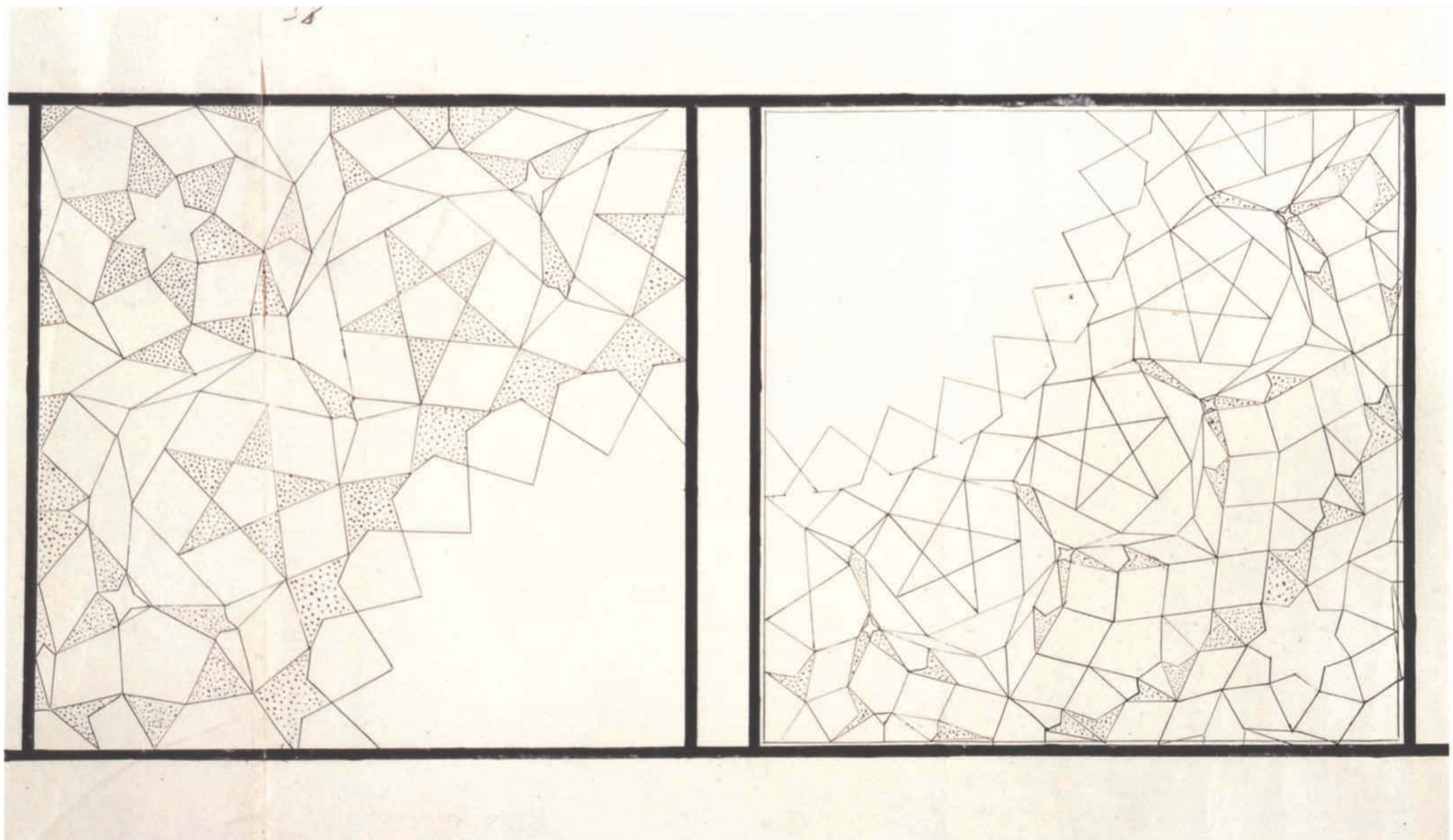


106 b c 107 a b



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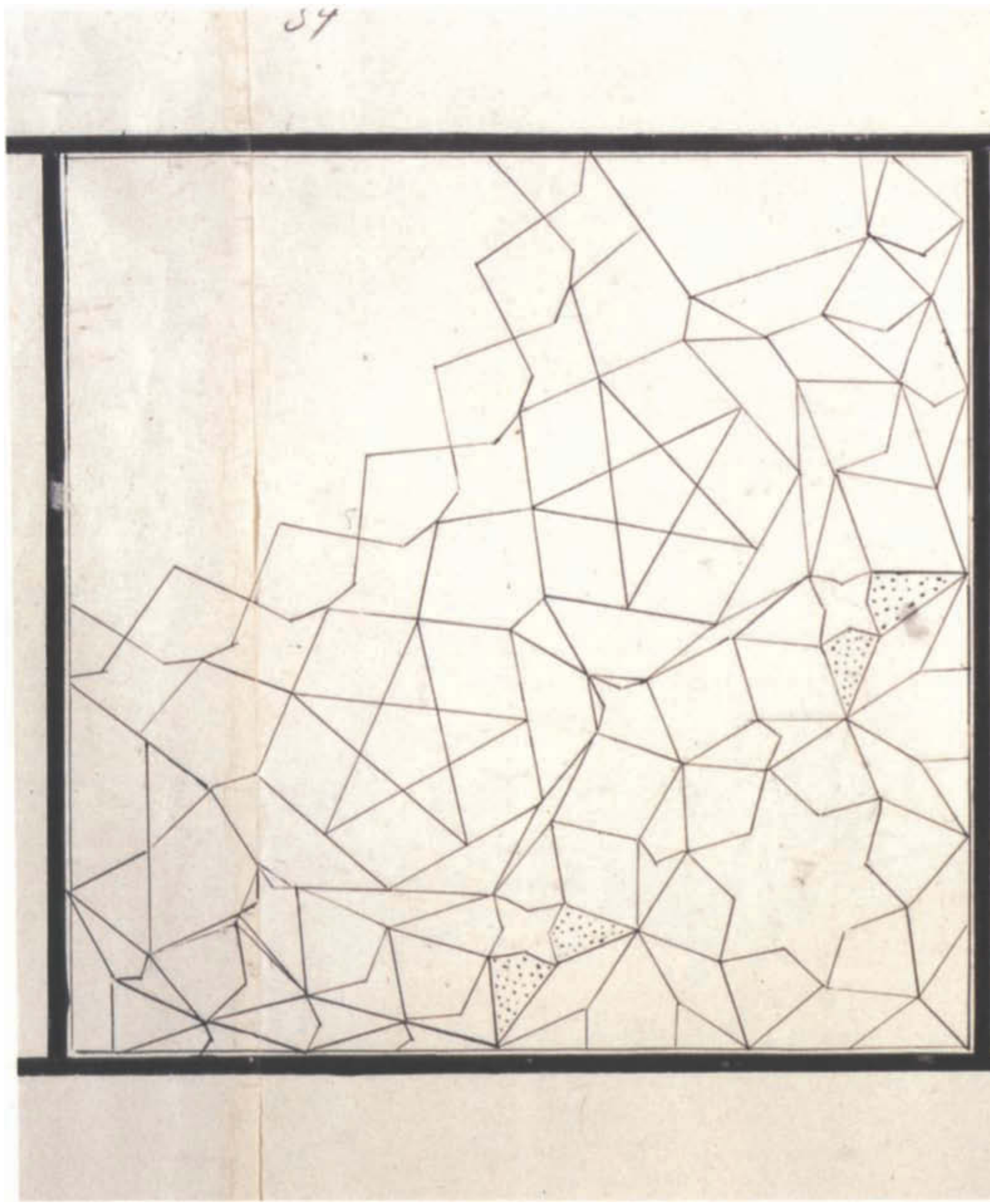

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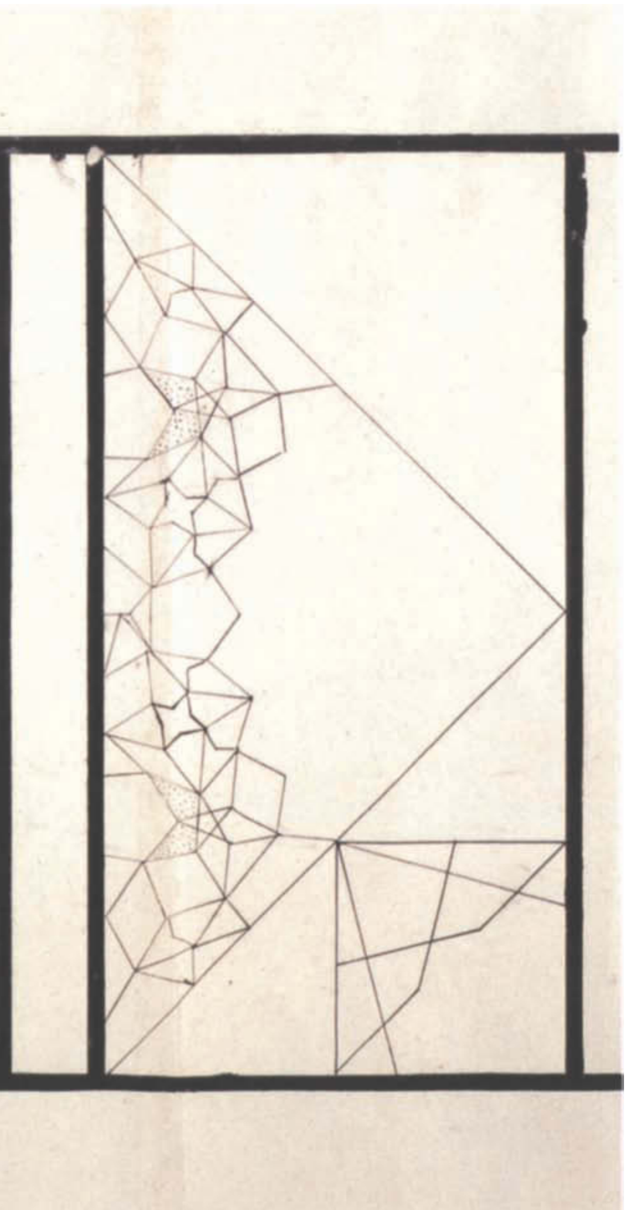

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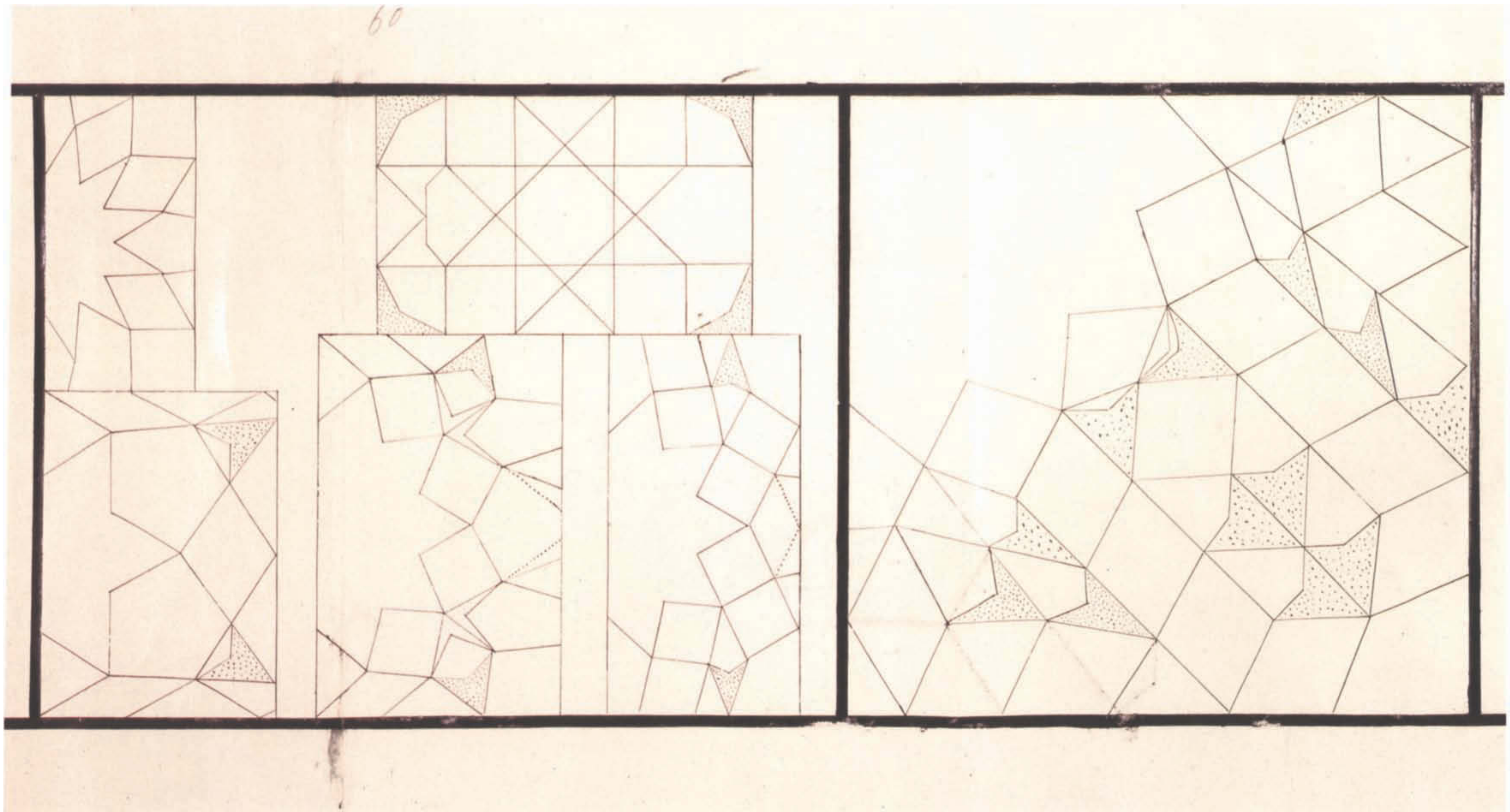

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THE MUQARNAS: A GEOMETRIC ANALYSIS BY MOHAMMAD AL-ASAD

The muqarnas is a vaulting system based on the replication of units arranged in tiers, each of which supports another one corbeled on top of it. The final result is a stairlike arrangement that is sometimes referred to as honeycomb or stalactite vaulting. The units are made of wood, brick, plaster, or stone and can be painted, or, as in the case of the brick or plaster ones, covered with glazed tiles. Muqarnas compositions can be located in different parts of a building, articulating a column capital, supporting a minaret's balcony, or vaulting over an entry portal, niche, or hall. Muqarnas vaults are usually part of a double-shell arrangement and are therefore visible only from the inside of a building. In some cases, as in the mausoleums of Nur al-Din in Damascus (1172) and Imam Dur in Samarra (circa 1085), the muqarnas is also reflected on the outside.

The muqarnas can fulfill a structural role. The muqarnas vaults of the main dome of the fourteenth-century Cairene madrasa of the sultan Barquq (r. 1382–1398), for example, function as pendentives providing a transitional zone between the square base and the circular dome. Most muqarnas vaults, however, are purely decorative, and their units are suspended from, or connected to, a structural element. For example, the muqarnas vaults covering the Hall of Two Sisters and the Hall of the Abencerrajes (constructed in the fourteenth century) of the Alhambra in Granada consist of nonstructural plaster units suspended from the roofs.

The chronological and geographic origins of the muqarnas are controversial subjects. Tenth-century northeastern Iran, eleventh-century North Africa, and eleventh-century Baghdad have all been proposed as centers from which the muqarnas might have originated.[1] What is definite is that by the twelfth century the muqarnas had become a common unifying feature connecting the diverse architectural productions of the Islamic world, from North Africa to Iran. As Grabar has pointed out, the muqarnas "is an entirely Muslim invention . . . and it is a form used in all kinds of Islamic monuments, not only mosques."[2]

In spite of its importance as a signifier of the architecture of the Islamic world, and although a large number of monuments containing muqarnas compositions have survived, this architectural feature remains little understood. The debate continues concerning when and where it originated. Taxonomic documentation cataloging its formal and technical characteristics is incomplete and scattered among numerous studies. Even the etymology of the word *muqarnas* is unclear.[3] According to one source, it is borrowed from the Greek word *koronis,* which is also believed to have supplied the English word *cornice.*[4] According to another, it is derived from the Greek word for roofing tiles.[5] If one looks up the root *qrns* or *qrnṣ* in medieval Arabic lexicons such as Ibn Manzur's *Kitāb Lisān al-ʿArab,* 1291, and al-Fayruzabadi's *al-Qāmūs al-Muhīṭ wa al-Qāmūs al-Waṣīt,* 1414, one finds that the muqarnas is not even defined as an architectural element because medieval Arabic dictionaries record mainly the language of the bedouin Arabs of pre- and early Islamic times and therefore often do not include technical terminology that originated in cultural centers outside the Arabian peninsula. Words listed under the root *qrns* or *qrnṣ* have other meanings including a technical term in falconry (*qirnās*), a sword in the

shape of a stair (*muqarnaṣ*), and an overhanging cliff (*qirnās* or *qurnās*).[6] This last meaning may be the one from which the architectural term *muqarnas* developed since both are based on the idea of corbeling. The etymological connection between the topographic *qirnās* and the architectural muqarnas is alluded to in Persian lexicons such as ʿAli Akbar Dihkhuda's (1879–1955) *Lughat-nāmā*. In contrast to the difficulty faced in finding an architectural meaning for the word *muqarnas* in medieval Arabic dictionaries, in the mathematical treatise *Miftāḥ al-ḥisāb* written in Arabic by al-Kashi, the term describes the same architectural feature known to us today.[7]

The study of the muqarnas is complicated by the lack of contemporary texts describing it. Medieval texts from the Islamic world are generally silent about their architectural surroundings. The primary surviving discussion of the muqarnas is a short section in al-Kashi's *Miftāḥ al-ḥisāb* that contains a relatively detailed geometric analysis.[8] Another set of contemporary documents dealing with the muqarnas consists of surviving plan drawings of muqarnas compositions. These include the muqarnas plans found in the Topkapı scroll, those made by a sixteenth-century architect of Bukhara, and the Ilkhanid clay tablet representing a plan of a muqarnas vault found in excavations of Takht-i Sulayman. More recent examples include nineteenth-century scrolls belonging to Mirza Akbar, which are now in the Victoria & Albert Museum.[9] Moroccan artisans continue to use such plans for constructing muqarnas vaults today.[10] Although unannotated, these visual documents can help us understand how medieval geometers, master builders, and artisans represented the muqarnas and communicated information about it to each other.

One of the most fascinating characteristics of the muqarnas is its geometry. Although often analyzed, by numerous authors ranging from Jones and Goury in the nineteenth century to more contemporary scholars such as Notkin and Michel Ecochard, the muqarnas remains a mystery to most architectural historians, partly because of the mathematics required for its analysis.[11] It can, however, be studied at different levels of mathematical intensity, and it was not only discussed by mathematicians such as al-Kashi but also designed and constructed by artisans of modest education with only a basic knowledge of Euclidean geometry.

Geometric analysis requires dissecting the muqarnas into its component parts, that is, its tiers and units. One must shift to a different level of perception, one in which the gestalt is ignored and the individual unit becomes the primary focus of attention. In plan, most muqarnas formations consist of triangular and quadrilateral units. In some instances other geometric shapes, such as floral, polygonal, and star patterns, can also be found. In later muqarnas vaults, such as thirteenth- and fourteenth-century Spanish and North African ones, muqarnas units incorporate tapering projections that hang from the ceilings, which explains how the term *stalactite* came to be attached to this vaulting system. In plan, the outline of these tapered units is identical to that of nontapered ones.

Any geometric analysis of the muqarnas will fall partially under the heading of stereometry as a result of its three-dimensional character. On the levels of the individual unit, row, or whole composition, the muqarnas always involves all three coordinates of width, height, and depth. Representing the muqarnas in plan or elevation, or even a combination of both, does not clearly communicate its three-dimensional character. Such drawings only provide two of the dimensions and have to be supplemented by three-dimensional representations. Harb provided isometric drawings of his interpretation of the muqarnas clay tablet excavated at Takht-i Sulayman, and Notkin constructed a wooden model of a muqarnas vault for his interpretation of one of the Bukharan drawings in Tashkent.[12]

To show how a muqarnas plan is transformed into a three-dimensional composition, one of the muqarnas plans of the Topkapı scroll (see cat. no. 5) will be used as an example. The drawing represents a quarter vault whose apex is located at the lower right corner of the frame. If duplicated along its right or lower border, the quarter vault is transformed into a half vault similar to those covering entry portals. The drawing represents what has been described in the catalog of pattern types as a fan-shaped radial muqarnas vault. It consists of a quarter vault at the lower right with muqarnas units filling the remaining part. A

number of the units are highlighted with red ink, black ink, or black dots. The drawing also contains grid or construction lines incised with a sharp instrument (see overlay of cat. no. 5). These radially organized lines (reproduced with slight adjustments in ill. 1 as gray lines) consist of raylike straight lines and concentric quarter circles centering on the lower right corner of the drawing frame. A group of smaller concentric circles and half circles are centered along the straight raylike construction lines and are divided by a series of radii. These arrangements define the four-, five-, and eight-pointed stars of the drawing.

The straight construction lines emanating from the lower right corner of the drawing divide it into twelve segments. Of these, the central diagonal line connecting the lower right and upper left corners divides the composition into symmetrical halves. The symmetry is partially broken at the lower left side of the drawing, which would be expected to contain half of a five-pointed star arrangement completing the row of five-pointed stars occupying that part of the drawing. The broken symmetry suggests that the drawing was not meant to be quadrupled into a full vault but used only as a half vault.

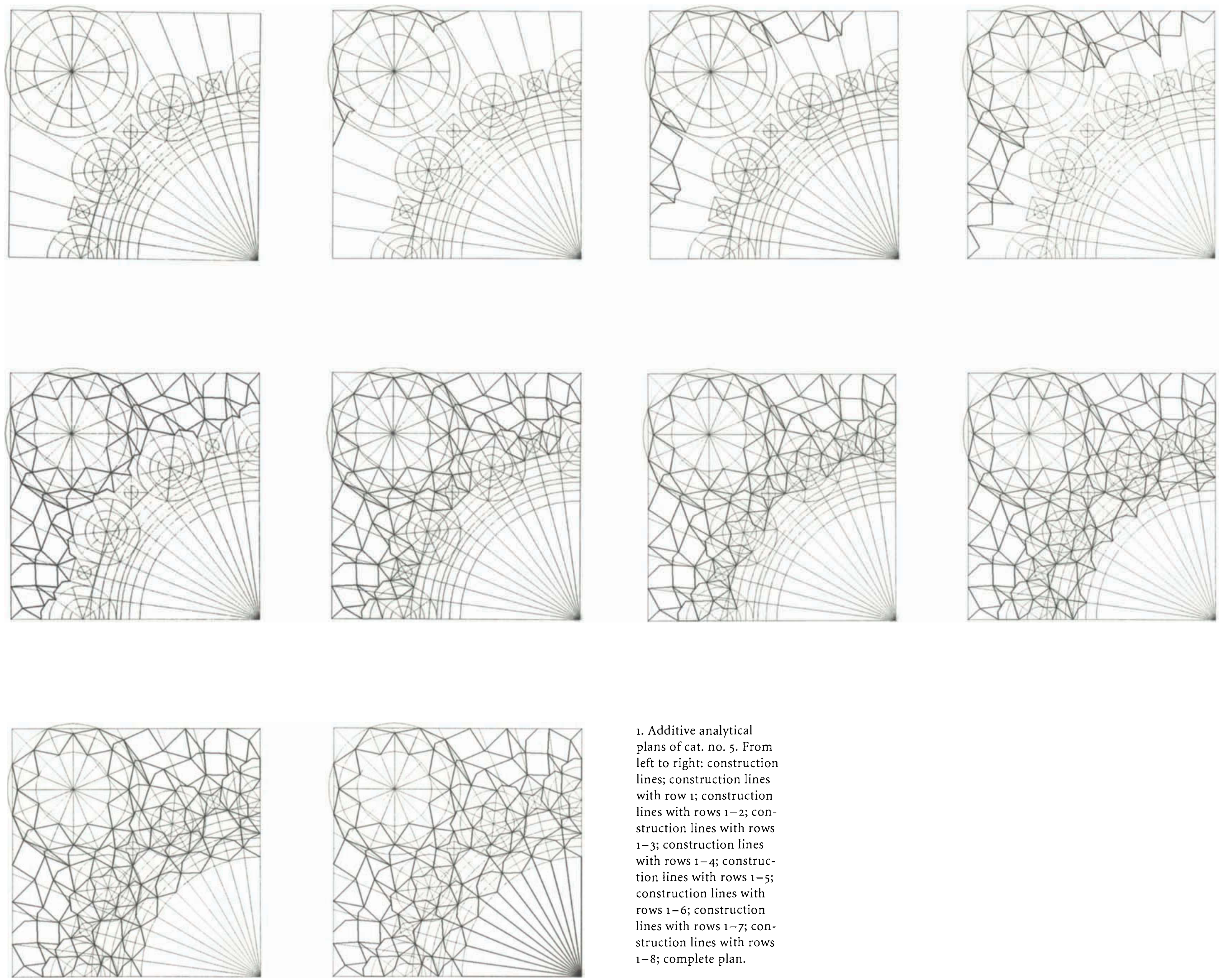
The units located within the boundaries of the circular and quarter-circular construction lines are regular in plan and are organized according to a radially symmetrical system. The units located outside these organizing lines, in the upper right and lower left sides of the frame, lack this regularity and are symmetrical only along the central diagonal construction line. These irregular units represent the transitional areas between the square base and the circular half vault.

A few comments should be made concerning the accuracy of premodern drawings such as those of the Topkapı scroll. The intention of the draftsman was clearly that of dividing the frame into twelve equidistant segments with lines emanating from the lower right corner and separated from each other by an angle of 7.5 degrees. The intersection points of some of the construction lines are intended to locate the centers of the four-, five-, and eight-pointed stars, divide a unit in half, or locate the points of intersection of two or more units. However most of the construction lines do not pass through the exact intended location, and grid lines that are supposed to intersect at one point, or pass through the intersection point of two units, do not. Such deficiencies are understandable. Considering the inaccuracy of drafting instruments before the modern era, making such a large number of lines pass through the exact intended points must have been a difficult task. Since these drawings probably functioned as sketchbooks or source books of patterns and since they adequately communicate the intentions of the designer, exacting standards of precision were not required.

Using Computervision CADDS4X, a computer-aided design program, I converted cat. no. 5 into a three-dimensional composition.[13] Such programs are a valuable tool for constructing complex three-dimensional objects and offer numerous advantages over traditional drafting methods; the user can make changes with relative ease, view the constructed object from an unlimited number of angles and distances, and easily replicate repetitive units. This last facility is important since even the most irregular muqarnas compositions include a good deal of repetition. With a computer-aided design program, the constructed object can be divided into separate layers, each of which can be viewed or worked on separately. Another important advantage of such programs is that any point fed into the computer needs to be specified according to its three-dimensional coordinates capable of producing isometric views. This is in contrast to the situation encountered with two- or even three-dimensional designs drawn by hand, which only provide one view of the constructed object and do not preserve three-dimensional information but translate it to the single two-dimensional plane of the drawing surface.

When reproducing the plan here (see ill. 1), a number of modifications were made, some of them for the sake of realizing the intentions of the designer. Since computer-aided design programs can achieve high degrees of accuracy, lines that were intended to cross at one point have been made to do so even if they do not cross that point in the actual drawing. In addition, the arrangement of units in the lower left side of the frame was modified to complete the radial symmetry of the row of five-pointed stars.

Since a plan drawing can contain only limited information about a muqarnas formation, trans-

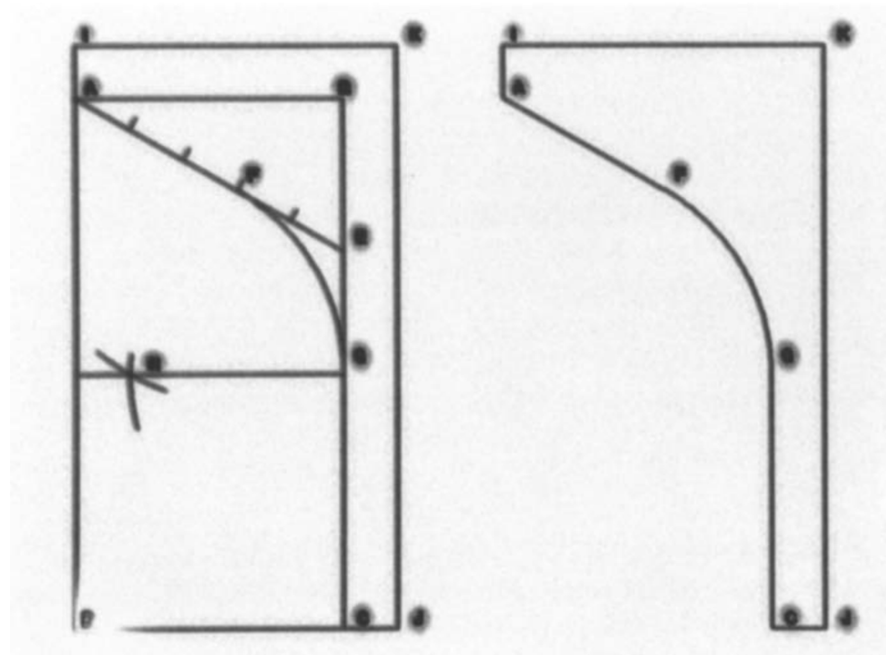


1. Additive analytical plans of cat. no. 5. From left to right: construction lines; construction lines with row 1; construction lines with rows 1–2; construction lines with rows 1–3; construction lines with rows 1–4; construction lines with rows 1–5; construction lines with rows 1–6; construction lines with rows 1–7; construction lines with rows 1–8; complete plan.

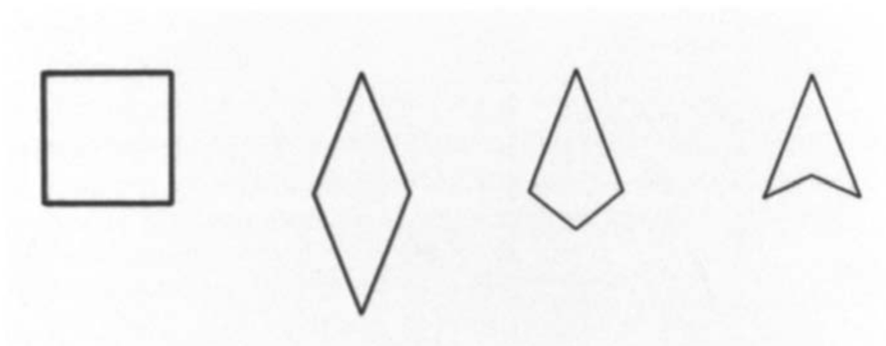
forming it into a three-dimensional composition is an interpretative process in which the interpreter needs to supply the missing data. Although the coding of some of the plan units with dots and colors provides some of that information, one still has to make use of the information provided by other sources such as surviving examples of muqarnas vaults and al-Kashi's section on the muqarnas in his *Miftāḥ al-ḥisāb.* Even so, no single correct three-dimensional interpretation of the plan exists and what is provided here is only one version of the possible interpretations. Although the conversion of these plans into three-dimensional objects may seem to the modern eye to be a highly interpretative process, it was standardized for medieval artisans. During that period, the procedure was a carefully guarded secret known only to members of guilds, who often belonged to the Sufi orders, or *ṭarīqa*s, and underwent the required years of apprenticeship under the guidance of a master craftsman.

Although the language of al-Kashi's *Miftāḥ al-ḥisāb* is often obscure and parts of it are difficult to decipher, it remains a valuable source. Much of al-Kashi's discussion is devoted to the measurement of surface areas, and the goal of the section on the muqarnas probably was to provide a method of calculating the amount of materials needed for the construction of muqarnas vaults.[14] In his discussion, al-Kashi mentioned that a muqarnas composition is divided into tiers (*ṭabaqa*) that in turn are divided into units (*bayt*). He also enumerated the different types of muqarnas vaults: the plain or simple (*sadhijj*), clay-covered (*muṭayyan*), arch (*qaws*), and Shirazi (*shīrāzī*). The *sadhijj* is the simplest of the four and is characterized by angular elevational outlines; the *muṭayyan* is similar to the *sadhijj* except that its tiers are not all of the same height; and the *qaws* has curving elevational outlines. The Shirazi is the most complex of the four. Unlike the other types, which in plan consist exclusively of triangles and quadrilaterals such as squares, rectangles, bipeds, rhombuses, and rhomboids, a Shirazi muqarnas contains other polygons such as pentagons, hexagons, octagons, and multipointed stars. Golombek and Wilber stated that in contrast to the three other types, which are organized according to an orthogonal grid, the Shirazi is organized according to a radial grid.[15] The drawing used in this study (cat. no. 5) is an example of a Shirazi muqarnas.

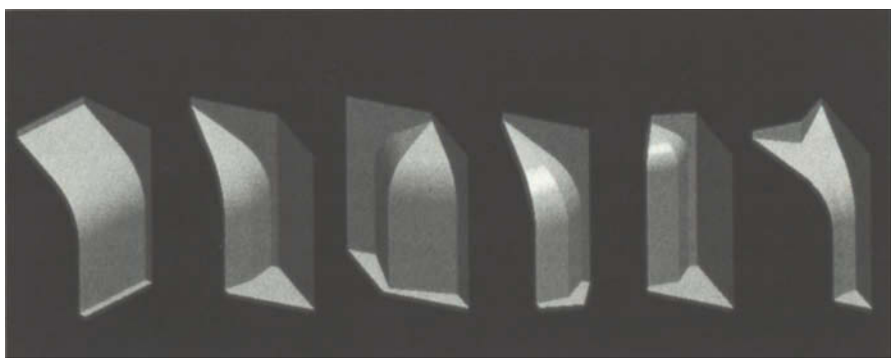
To supplement his section on the muqarnas, al-Kashi included two drawings. The first consists of plans of individual units identified as a square, rhombus, biped, lozenge (*lawza*), and a *jawdanaj* (an elongated lozenge or "barley grain"). The lozenge and *jawdanaj* are both rhomboids. The second drawing, which accompanies an addendum to the section, illustrates the elevational curvature of the ceiling of a muqarnas unit (ill. 2).[16] It is of extreme importance since other surviving drawings of the muqarnas consist only of plans; information concerning the third dimension was generally communicated by word of mouth. This drawing accompanies an explanation of how the curvature of a muqarnas unit is obtained. Here



2. From left to right: An illustration based on the drawing accompanying al-Kashi's addendum explaining how to calculate the curvature of the ceiling of a muqarnas unit; resulting outline of the elevation of a muqarnas unit.



3a. Plans of square, rhombus, rhomboid, and biped muqarnas units.



3b. Three-dimensional interpretations of muqarnas units. From left to right: square; rhombus with curvature located along one of the acute angles; rhombus with curvature located along one of the obtuse angles; rhomboid with curvature located along one of the acute angles; rhomboid with curvature located along one of the obtuse angles; biped unit.

al-Kashi also mentioned that the height of a unit should equal approximately twice its depth. However he added that height is a flexible dimension that can be lengthened or shortened. Such flexibility in the ratio of height to width is unavoidable since the units of a muqarnas tier do not necessarily have the same depth, but they generally have the same height.

With the aid of the guidelines provided by al-Kashi, muqarnas plans can be converted into three-dimensional compositions. I began by interpreting the basic individual unit plan of the square, rhombus, rhomboid, and biped (ills. 3a, 3b). Other units are variants of these basic ones, differing only in proportions and degree of regularity. It turned out that two interpretations are possible for each of the rhombus and rhomboid plans. Which is used depends on the position of the curvature, which can be located along either the obtuse or acute angles of these quadrilaterals. The correct position of the curvature is determined by the orientation of the unit within the muqarnas composition.

The plan of the muqarnas quarter vault has units coded with dots and colors; this coding proved to be informative even though it cannot be completely deciphered. In some cases different types of units have the same coding, and in others, similar types of units are provided with different coding. Although all bipeds are highlighted, for example, the uppermost row of double bipeds is dotted, but the remaining ones are colored. In addition to the first row of double bipeds, a number of the units surrounding the stars are dotted. These include one of the units surrounding the four-pointed stars, four of the units surrounding the five-pointed stars, and six of the units surrounding the eight-pointed star. These dotted units are located on a lower tier than the unmarked ones, and the curving surfaces of the dotted units face the center of the stars they surround, but the curving surfaces of the empty ones face away from the star centers. Even though the use of color is mainly reserved for bipeds, it is also applied to some of the four-pointed stars and some of the triangular units located along the edge of the frame.

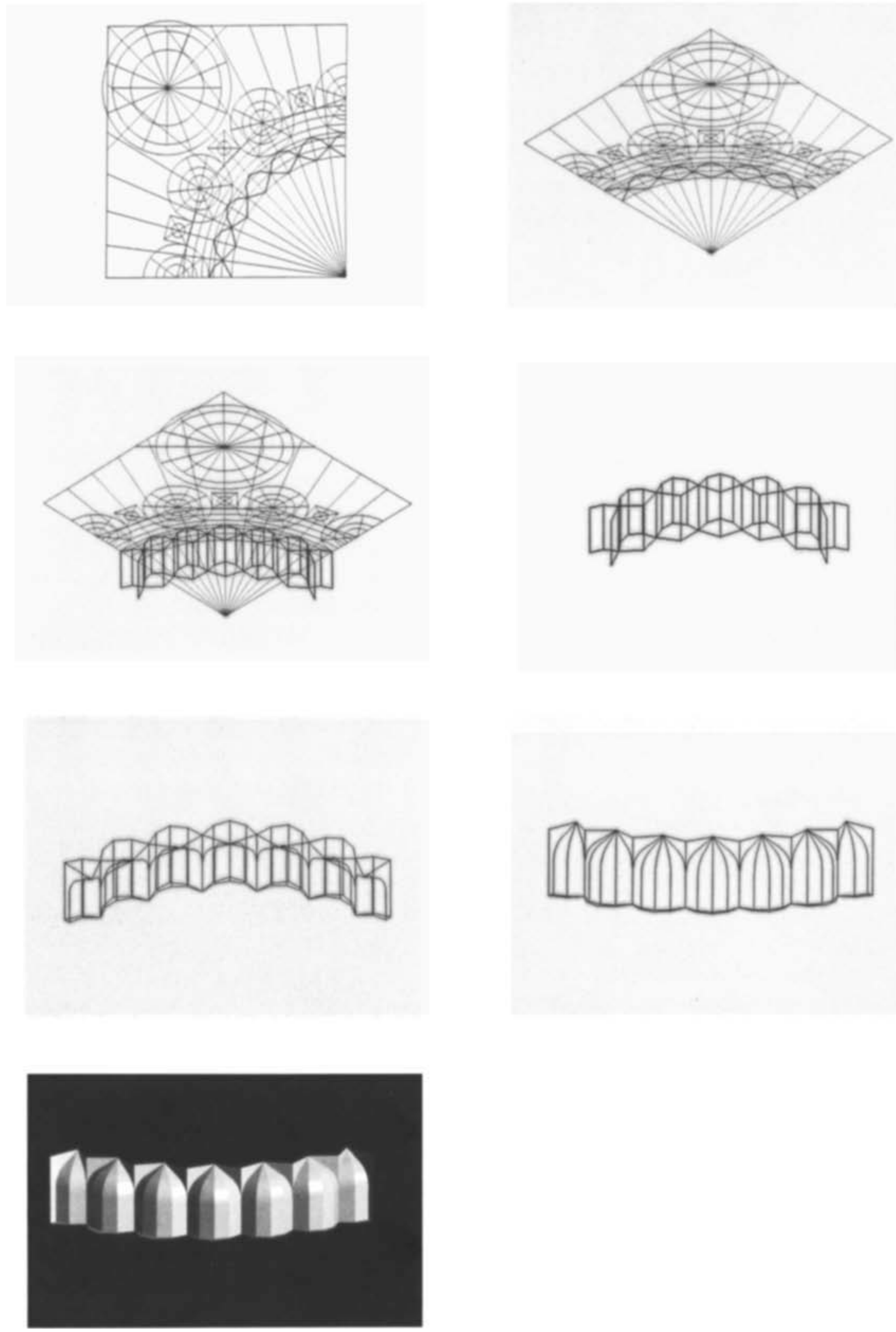
A necessary step in transforming a muqarnas plan into a three-dimensional composition is dividing it into its component rows. In plan, a row represents a tier of single units of equal height placed adjacent to each other. Often a tier is accompanied by a row of bipeds occupying the same elevational position. In elevation, a tier of bipeds is never separate but is always located in front of a tier of nonbipeds. In contrast to other quadrilateral units such as rectangles and rhombuses, biped units taper toward the bottom and therefore do not have the necessary width to sustain a tier independently.

As al-Kashi pointed out, tier height is a flexible dimension to be determined by the aesthetic judgment of the builder, the profile of the arch or vault surrounding the muqarnas, and the overall formal characteristics of the space in which the muqarnas is located. In order to simplify the process of providing a three-dimensional projection

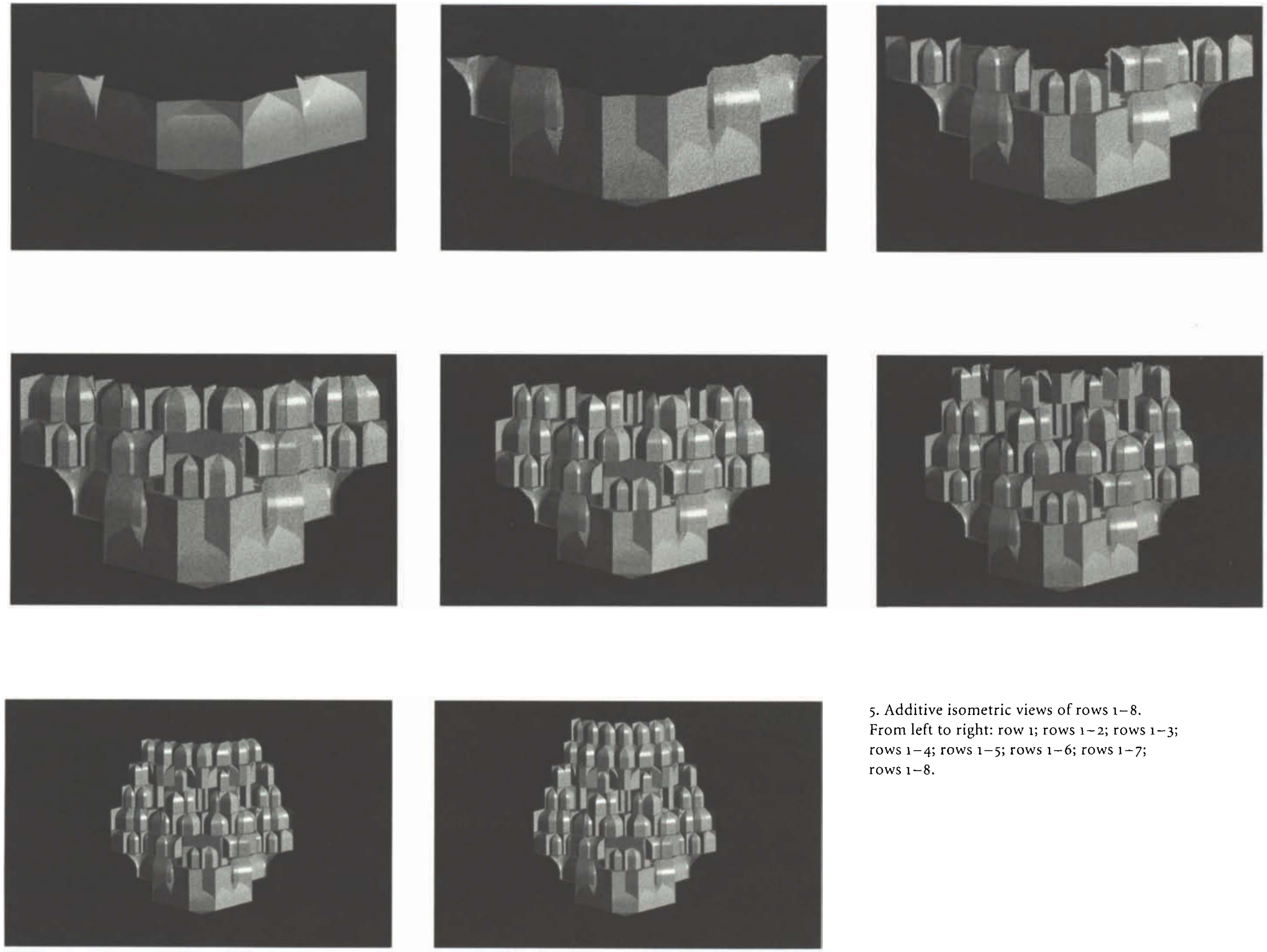
of the plan analyzed in this study, one height has been used for all tiers. The uppermost tier was designated as the reference tier. It is the most regular tier and consists only of identical units and half units. The height used for the tiers equals twice the depth of the units of the uppermost row. Another interpretation based on a different height, or heights, for the tiers would be equally correct.

The plan can be divided into eight rows, most of which support a row of bipeds. The top four rows (rows 5–8), which are located within the boundaries of the circular construction lines, are regular in plan, and are arranged according to a system of radial symmetry. The bottom four rows (rows 1–4), which are located in proximity to the outer edges of the muqarnas, are irregular and are only symmetrical along the diagonal axis connecting the upper left and lower right corners of the plan. One partial exception to this group of irregular rows is the one containing the units forming the eight-pointed star located in the upper left corner of the plan. This star is defined by construction lines consisting of three concentric circles that are divided into sixteen equal segments by sixteen radii separated from each other by an angle of 22.5 degrees. The units surrounding each of the stars are divided among two adjacent tiers, the dotted ones belonging to the lower tier.

The process of transforming a row from a plan into a three-dimensional composition is demonstrated in illustration 4, which uses the eighth and uppermost row as an example. The plan is first projected by the determined height. The curving



4. Process of transforming a plan of a muqarnas row into a three-dimensional composition. From left to right: plan of a row with construction lines; isometric of the plan; projection of a row with construction lines; projection of a row without construction lines; carving of muqarnas units out of projection; worm's-eye line drawing of a muqarnas row; worm's-eye shaded image of a muqarnas row.

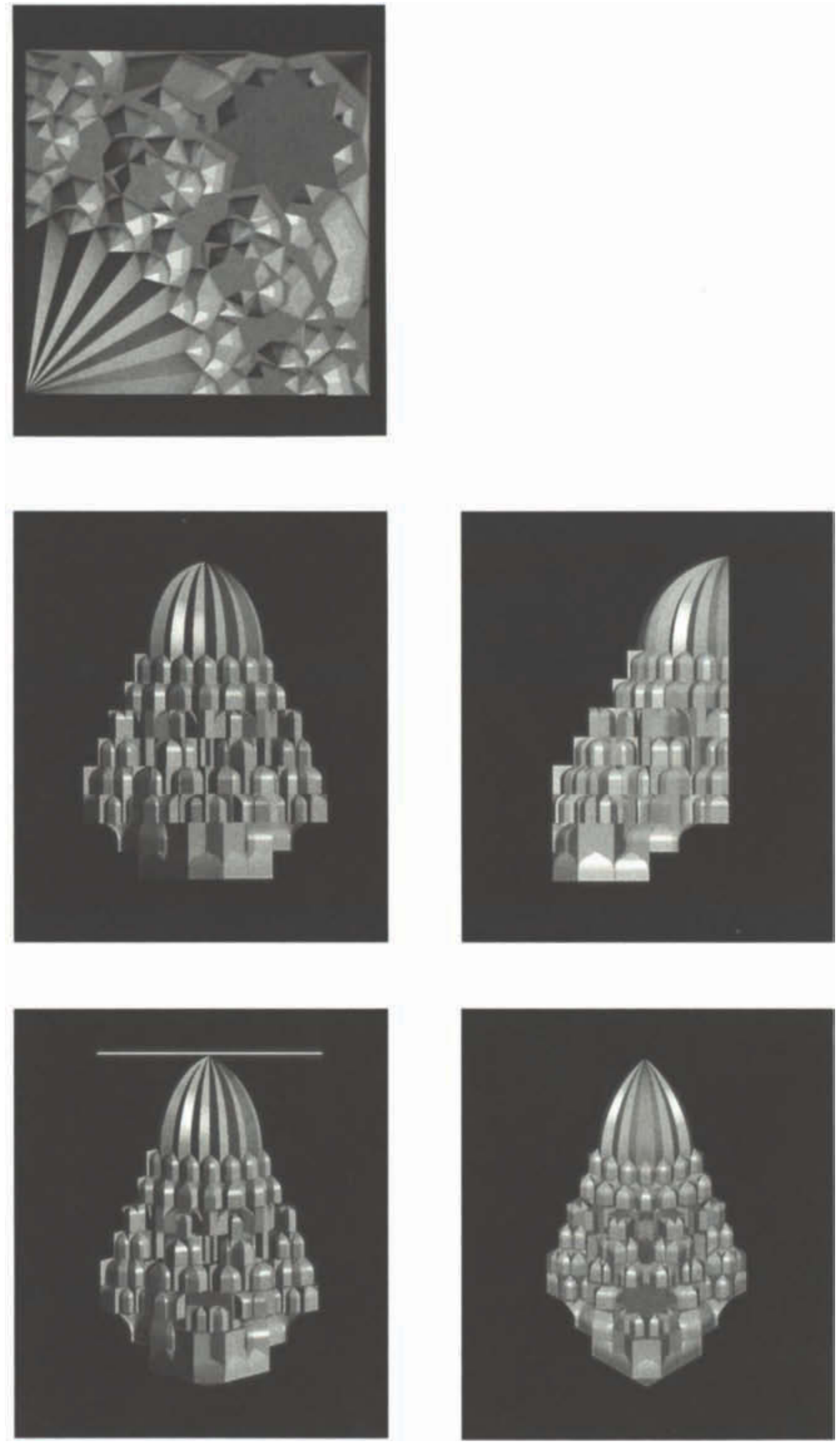


5. Additive isometric views of rows 1–8. From left to right: row 1; rows 1–2; rows 1–3; rows 1–4; rows 1–5; rows 1–6; rows 1–7; rows 1–8.

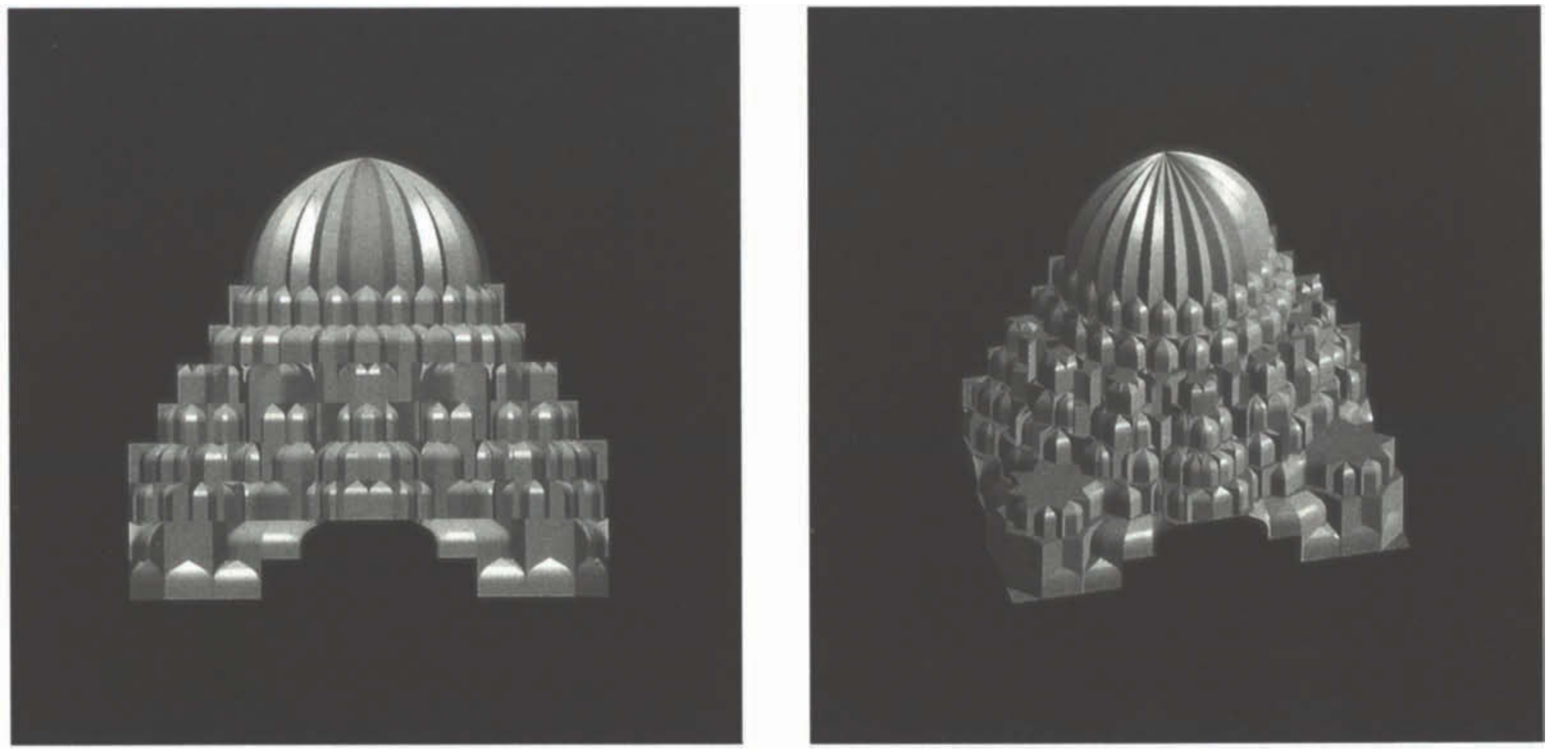
outlines of the muqarnas units are then carved out of the projection according to the guidelines provided by al-Kashi in the addendum to his chapter. As the process of projection and carving is repeated for each tier, care must be taken to place that tier in its correct elevational position. The highest plane, or roof, of each tier should be placed at the same level as the bottom plane of the tier located above it. In the final result, each row maintains its location in plan and is only shifted along the height coordinate (ill. 5).

The final product of this process of projecting, carving, and shifting represents a quarter vault (ill. 6). If mirrored along either the right or lower side of the frame of the plan, the result is a half vault similar to those placed above entry portals (ill. 7). When placing a muqarnas half vault behind the arch of such a portal, the muqarnas arrangement needs to be fitted within the outlines of the arch. There is considerable flexibility in achieving this. For example a large number of outlines are available for arches since they can be designed according to one, two, three, or four centers.[17] Any muqarnas vaulting arrangement also can be made to fit within the boundaries of an arch by adjusting the heights of its tiers. Illustration 8 shows the constructed half vault placed behind the four-centered arch of an entry portal. In this case the tier heights were left unchanged, and only the half dome was flattened to correspond more closely to the outline of the crown of the arch. The irregular units along the edges of the muqarnas plan facilitated adjustment to particular arch profiles.

One aim of this study has been to analyze the muqarnas on the levels of two-dimensional representations and three-dimensional compositions. The muqarnas constructed here resembles a product of the Timurid era. To achieve a better understanding of the muqarnas, similar investigations covering a wider geographic and chronological distribution need to be carried out. The results of such investigations, however, will fill only part of the gap in our understanding of the muqarnas. Information reaching us from the past is most often fragmentary and incomplete. Our knowledge of the muqarnas, including its origins, planning processes, construction methods, and meanings, remains deficient. In order to correct such deficiencies, we not only need to examine the available contemporary visual documents of surviving structures and drawings but also to look at other sources such as poetry, a body of information that still has not been used effectively by historians of the architecture of the Islamic world. It is only through such additional research that our conclusions concerning the muqarnas as an architectural and iconographic element can be more definitively removed from the realm of the conjectural.



6. Views of completed muqarnas quarter vault. From left to right: plan; frontal elevation; side elevation; worm's-eye view of inside of vault; bird's-eye view of outside of vault. Note that muqarnas units are rarely expressed on the outside of a structure except in a few examples such as the mausoleums of Nur al-Din and Imam Dur. Since views of convex forms are easier to grasp visually than those of concave forms, however, a view of the outside of a muqarnas vault better explains its formal qualities than a view of the inside.



7. Elevation and bird's-eye views of the outside of a muqarnas half vault.

8. View of a muqarnas half vault placed within an entry portal.

Translation of al-Kashi's Addendum to His Chapter "Calculating the Surface Area of the Muqarnas"[18]

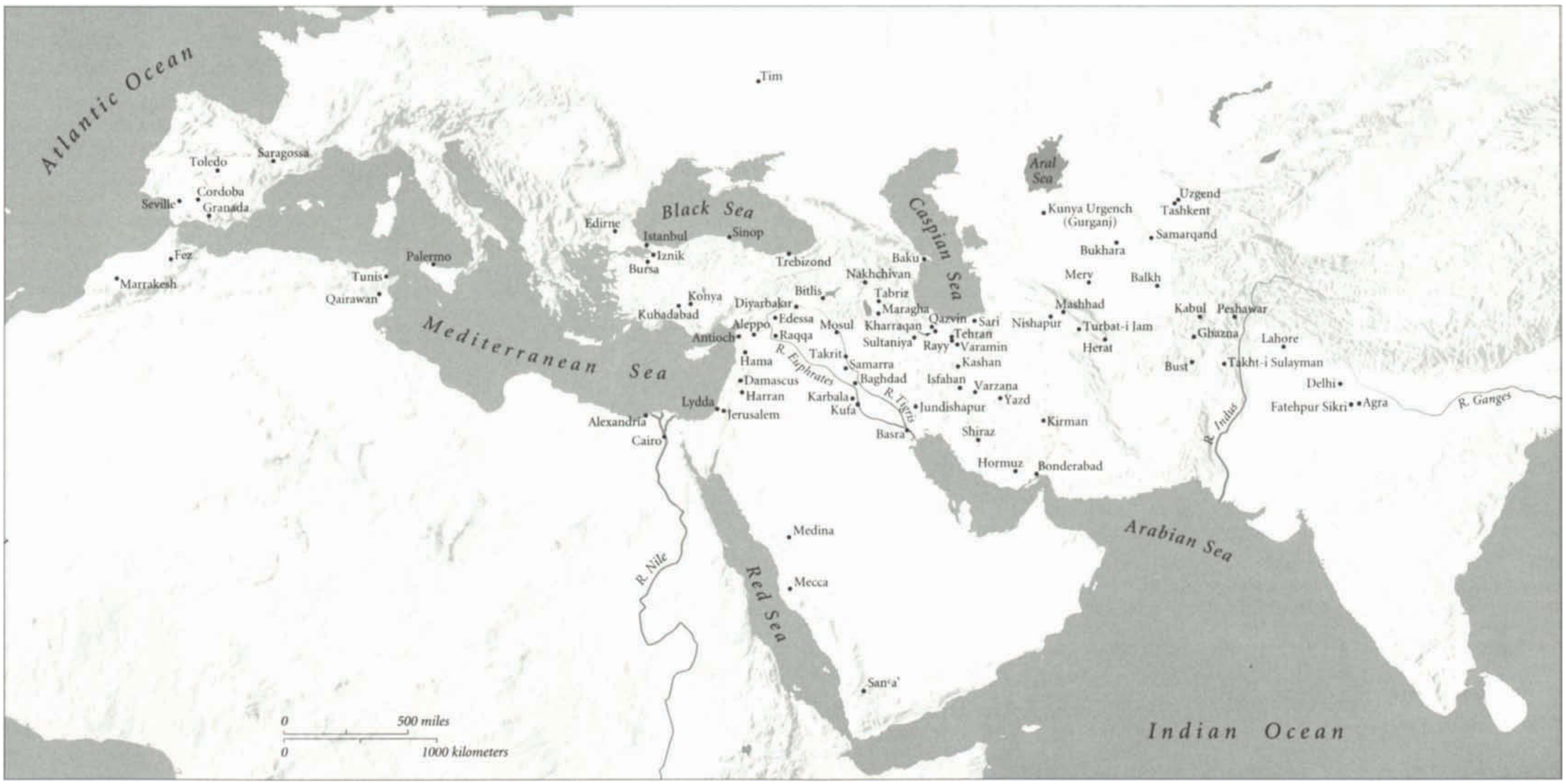
Builders draw a rectangle whose width equals the module [*miqyās*] of the muqarnas, and length equals twice the width, as in rectangle ABCD. Line AE is constructed at angle A° which creates along with line AB a third of a right angle (30°). AE is then divided into five equal sections. From point E, lines EF and EG, both of which are equal to two-fifths of line AE, are constructed. An arc with a radius equal to FG is constructed from each of points F and G. The two arcs intersect inside the rectangle ABCD at point H. From point H, arc FG, which in length will have to equal one-sixth of the circumference, is constructed. Lines DA and DC are extended to reach points I and J. From them, line KJ, which is parallel to line BC, and line IK, which is parallel to line AB, are constructed. Numerous gypsum boards corresponding to surface KIAFGCJ (of which FG is an arc) are made. Each two define a muqarnas unit in which line CG is perpendicular to the ground. . . .

It is possible to shorten or lengthen the leg of the board, meaning line GC. If placed behind an arch, this is needed for both of them (the muqarnas and the arch) to correspond to each other.

In surveying similar ones it is necessary to subtract from or add to the coefficient [*taʿdīl*][19] that which was subtracted from, or added to, the length of the leg of the board. What remains, or is acquired, can be used in place of the coefficient.

1. See Behrens-Abouseif 1993; Grabar 1978, 175–82; and Tabbaa 1985, 62ff.
2. Grabar 1988, 53.
3. Much of the following information on the etymology of the term *muqarnas* was provided to me through personal communication with Professor Wolfhart Heinrichs of Harvard University's Department of Near Eastern Languages and Civilizations.
4. See Diez 1987; and Herzfeld 1942, 1.
5. See Hoag 1977, 405.
6. A list of medieval Arabic lexicons containing definitions of the term *muqarnas* is found in Amin and Ibrahim 1990, 1.
7. See al-Kāshī 1969, 185. For more information on al-Kashi, see Vernet 1993. In the Muslim West, the term *muqarbas* was also used to describe muqarnas formations. See Fernández-Puertas 1993.
8. A discussion and English translation of al-Kashi's section on the muqarnas is found in Dold-Samplonius 1992a; and idem forthcoming. See also Golombek and Wilber 1988, 1: 164–69.
9. For a discussion of these drawings, see part 1 above.
10. See Paccard 1980, 280–305.
11. See Goury and Jones 1842–1845; Notkin 1970, 239–54; idem 1995; and Ecochard 1977.
12. See Harb 1978, figs. 1, 33; and Notkin 1995.
13. I would like to thank Jeffrey Barneson, Wade Hokoda, and Professor William J. Mitchell of Harvard University's Graduate School of Design for guiding me in using computer-aided design programs for the analysis of the muqarnas.
14. Golombek and Wilber 1988, 165; Dold-Samplonius 1992a; idem forthcoming. See also part 4 above.
15. Golombek and Wilber 1988, 167ff.
16. A translation of the addendum follows this essay.
17. For more information on the variety of arch designs found in Timurid architecture, see Golombek and Wilber 1988, 152–58. See also figs. 67–69 in the present book and Shiʿrbaf 1982–1983 for the method of contemporary master builders in modern Iran for constructing muqarnas portals.
18. For the Arabic version of this addendum, see al-Kāshī 1969, 187–88. The table containing surface area calculations of muqarnas cells and the part containing the lengths of segments of the elevational outline of a unit have not been included in this translation. A translation of the full addendum is provided in Dold-Samplonius 1992a; and idem forthcoming.
19. Al-Kashi defined the *taʿdīl* as GC + ½ AFG.

MAP OF THE ISLAMIC WORLD



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Simon Johnston, *Designer*
Suzanne Watson Petralli, *Production Coordinator*
David L. Fuller, *Cartographer*

Composed by G & S Typesetters, Inc., Austin, Texas,
in Minion type.
Printed by The Stinehour Press, Lunenburg, Vermont,
on Monadnock Dulcet, 100 lb. Neutral White Text.
Bound by Roswell Book Bindery, Phoenix, Arizona.

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